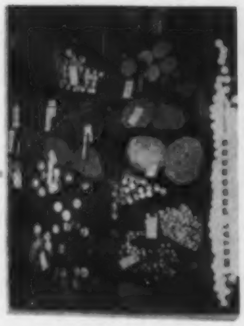
METAL PROGRESS AUGUST 1959

Metal Progress

August 1959....Volume 76, No. 2



Cover photo shows racks of bars in the plant of JOSEPH T. RYERSON & SON, INC. For details see p. 70.

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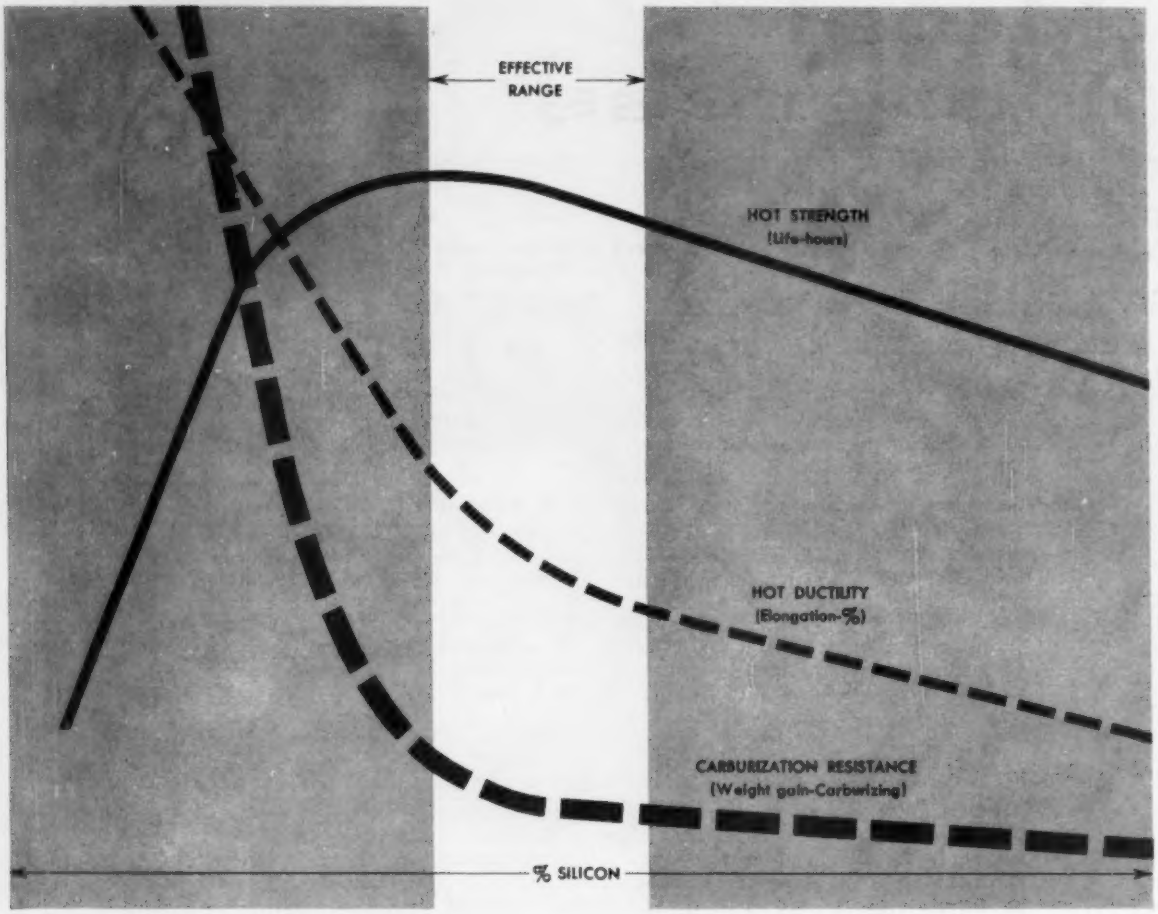
**The coding symbols refer to the ASM-SLA Metallurgical Literature Classification, International (Second) Edition, 1958*



How to use SILICON-CONTENT to lengthen the life of heat-resistant castings

Silicon content can be used to give heat-resistant alloy castings higher hot strength, higher hot ductility and higher carburization resistance.

But these property refinements are possible only within the relatively narrow *effective range* of silicon content shown on the graph. Silicon content lower than the effective range would result in a higher rate of carburization and low hot strength. Conversely, silicon content above the effective range, while it provides excellent carburization resistance, produces low hot strength and poor hot ductility.

The effective range of silicon content varies with operating conditions. Electro-Alloys' metallurgical research has defined a number of ranges to deal with these varying conditions.

To insure proper silicon content and the accurate balance of all alloying elements, consult us at the initial stages of product development. Electro-Alloys Division, 1018 Taylor Street, Elyria, Ohio.

AMERICAN Brake Shoe COMPANY

ELECTRO-ALLOYS DIVISION • Elyria, Ohio

Metal Progress

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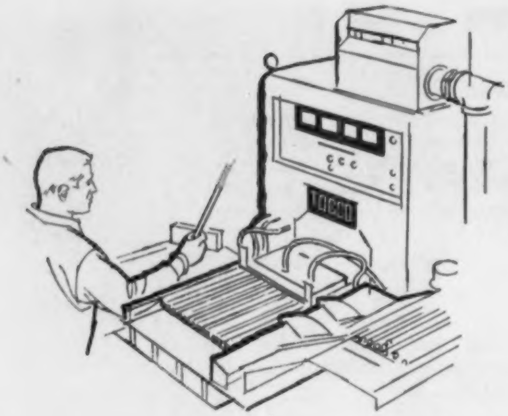
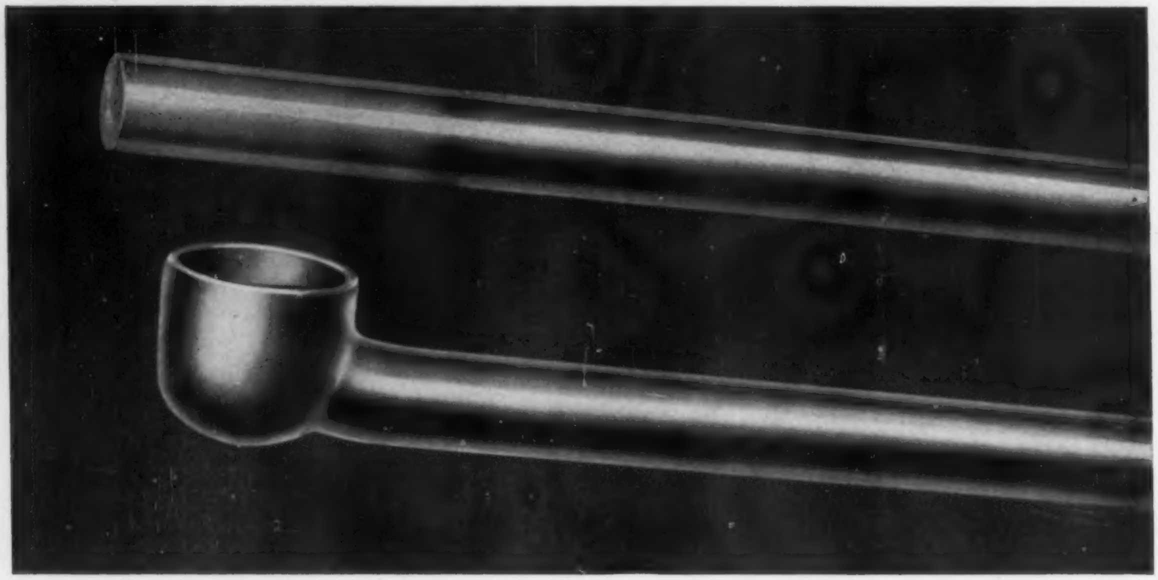


Heating Costs Cut In Half

with TOCCO* *Induction Heating*



Engineers at Thompson Products Inc.'s Michigan Division recently changed from gas-fired furnaces to fully automatic TOCCO. Application: heating for forging of automotive tie rods. Result: a substantial reduction in direct labor costs, saving thousands of dollars a year on this heating for forging operation. *Annual savings actually amortize the cost of the TOCCO installation in about one year.*

The automotive tie rod shown here is only one of over 500 parts heated for forging in Thompson's new, modern forge plant. *Every one of these parts is heated with TOCCO equipment.*

If *your* manufacturing operations require heating for forging, heat treating, brazing, soldering or melting, it will pay you to investigate TOCCO as a sound method of increasing production and lowering costs.

TOCCO

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THE OHIO CRANKSHAFT COMPANY

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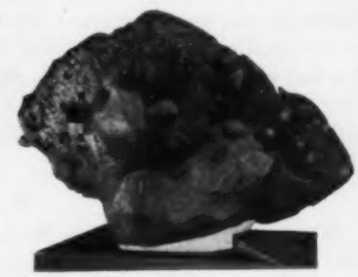
Press Breaks...

En route to Europe, vacationing Editor-in-Chief Thum sends us the following notes:

Sun-Lane News, the tabloid daily published on S.S. "Independence", Voyage 120–Eastbound No. 2, noted that Ray McBrian, chief of research for the Denver and Rio Grande Western Railroad (and it also might have mentioned, a long-time member of A.S.M.), believes that if soft pine railroad ties can be impregnated with formaldehyde and heavily irradiated by atomic reactor wastes they will acquire the strength and durability of oak. Also the last issue of *Newsweek,* read at home before leaving, had another item about Ray. This one was to the effect that soft coal, heavily irradiated, could be ground so fine it would become fluidized and could be substituted in whole or part for fuel oil. No telling what those ingenious metallurgists will come up with next!

A ten-day voyage to Italy gives one time to catch up on his reading – specifically a paper on meteorites which Herbert H. Uhlig, ⊕, professor at Massachusetts Institute of Technology, presented to a meeting of the American Assoc. for the Advancement of Science in December 1953. (Gosh, I *am* behind in my reading!) Meteorites, as is well known, are iron-nickel alloys and they often contain primary crystals a foot across, indicating that they took a long, long time to solidify and homogenize. Also there should have been plenty of time for equilibrium to be established on further cooling, whereupon the high-nickel gamma (taenite) should reject some low-nickel alpha (kamacite). In fact it does; the beautiful crisscross markings on a sectioned and polished meteorite are kamacite plates enclosing octahedral pieces of plessite (transformed taenite). The phases in this structure are analogous to those in coarse-grained steel – taenite corresponds to austenite, kamacite to primary ferrite, and the plessite corresponding to fine pearlite, bainite, or martensite.



Solid Iron Meteorite Displayed in the Hayden Planetarium in New York. (Courtesy General Electric Co.)

One mystery, however, is that the composition of these phases in actual meteors does not correspond to the boundaries in the iron-nickel binary diagram. Professor Uhlig explains this by saying that these meteorites stayed for eons deep down in a heavenly body the size of a planet where gravitational pressure is on the order of 3,500,000 psi., sufficient to lower the phase boundaries some 400° F. and move them to lower nickel content. When the lines of the diagram are so adjusted, that alpha and gamma boundaries are at about 6 and 13% Ni (the actual limits found in meteorites).

Furthermore, the time required for kamacite plates of measured dimensions to grow can be computed from the self-diffusion rate of nickel at the assumed temperatures; it comes out to be around three billion years, the estimated age of our solar system! Of course all this says is that the meteorite was a piece of an enormously big

Press Breaks . . .

and fairly hot body for 3 billion years; it gives no hint of where it came from originally.

Even though the gross structure of a meteorite indicates *very* slow cooling, the transformation products of the gamma solid solution (plessite) indicate *rapid* cooling. It was as though the gravitational pressure were suddenly released; the original heavenly body may have collided with another or exploded. This also explains the Neumann bands or shock wave effects which characterize a meteorite's microstructure.

Note that these conclusions by Professor Uhlig, relating to his own researches and analyzing a half-century of study by metallographers, were published six years ago. Just six months ago, three atomic scientists – Hess of America, Geiss of Switzerland and Begemann of Germany – announced the results of their studies of the 1948 shower of meteorites. By measuring the relative amounts of K^{40} and A^{40} and knowing the rates of decay of K^{40} and A^{40}, they estimated that the age of the meteorites was about 4 billion years – again, the life of our solar system, give or take a billion years. After the break-up of the large mass, the smaller fragments would show the effect of cosmic ray bombardment, and this was measured by the $H^3 \rightarrow He^3$ decay. The explosion or collision occurred 250,000,000 years ago.

While in the South attending the Southern Metals Conference (see this column, July issue), Editor Gray also had the pleasant task of spending a day at the Savannah River Plant in Aiken, S.C. (just across the Savannah River from Augusta), which is operated for the U.S. Atomic Energy Commission by the Du Pont Co. This visit was in behalf of the A.E.C.'s Advisory Committee on Industrial Information. The Editor was duly impressed with the increasingly important role which metallurgy and advanced metalworking techniques are playing in our atomic program. Phil Permar, metallurgical engineer at the plant and an active ASM'er, had arranged a very informative briefing session and tour of the facilities. (This was especially interesting to the Editor because he had worked on processes associated with this plant in 1951-52 at the Knolls Atomic Power Laboratory in Schenectady, N.Y.)

Managing Editor Marjorie Hyslop was one of the eighty-some "fascinated editors" (to quote *Time* magazine) who listened to President Eisenhower deliver a homey, off-the-cuff exposition of some of his views on the American economy. The occasion was a meeting of the Society of Business Magazine Editors in Washington early in June. The President's vigor, charm and personality made a startling impression on those of us whose only contact with him is through the distortions of a TV screen.

Earlier in the day the editors' program included a workshop session on layout, conducted by the well-known magazine artist George Samerjan. His points were vividly emphasized by examples and critiques of many of the magazines represented at the meeting, including *Metal Progress*. He characterized the cover of the April issue (our artist's conception of a powder metal press) as "daring, fresh and different", and commended our judicious use of color in the editorial pages. On the debit side we did receive some hints for – shall we say minor – improvement.

THE EDITORS

Metal Progress

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7301 EUCLID AVE., CLEVELAND 3, OHIO

ERNEST E. THUM, *Editor-in-Chief*

ALLEN G. GRAY, *Editor*

MARJORIE R. HYSLOP, *Managing Editor*

Assistant Editors

RALPH G. DERMOTT — CARL R. WEYMUELLER

FLOYD E. CRAIG, *Art Director*

ELIZABETH MCCALL ALDRICH, *Editorial Assistant*

Consulting Editors

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TAYLOR LYMAN, *Publisher*

A. P. FORD, *Sales and Advertising Manager*

PAUL HANCY, *Advertising Service*
7301 EUCLID AVE., CLEVELAND 3, OHIO

ADVERTISING OFFICES

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FRED STANLEY, *District Manager*
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GEORGE H. LOUGHNER, *Production Manager*
7301 EUCLID AVE., CLEVELAND 3—UTAH 1-0200

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Publishes *Metals Handbook*, an encyclopedia of metals; *Metals Review*, news magazine; *Review of Metal Literature*, abstracting service; *Transactions*, scientific annual; Career technical books on metals.

Educational activities: Operates National Western, and Southwestern Metal Congresses and Expositions; prepares and administers courses for Metals Engineering Institute for home, in-plant or American Society for Metals Chapter study.

READERSHIP Eastman RESEARCH

24' dia. expansion joints

To get highest possible quality.

Lewis Walker, president of Talon, Inc., left, discusses Shu-Lok with David Rae, general manager of the Shu-Lok Fastener Division.

"*We must have the best steel*"—says Carl M. Joslyn, plant manager of Shu-Lok Fastener Division, shown above with David Dibbell, Shu-Lok sales manager.

. Talon, Inc. starts with *Quality Steel*

Sharon supplies prime stainless for Talon's remarkable Shu-Lok

"The greatest thing that's happened to shoes since we killed the high button", say shoemakers. "A godsend"—agree mothers of little boys everywhere. Businessmen and athletes, too, are outspoken when describing the remarkable new Shu-Lok developed by Talon, Inc.

The Shu-Lok is an ingenious metal slide that "laces" shoes to the wearer's desired tightness instantly by simply pressing a small lever to the instep. Like all Talon creations the Shu-Lok is a highly perfected top quality product designed and built to provide years of service.

To make doubly sure it would do the job, Talon's engineering and production people decided to fabricate Shu-Lok of stainless steel. To make certain of the finest stainless, they came to a leading stainless producer, *Sharon Steel Corporation, Sharon, Pa.*

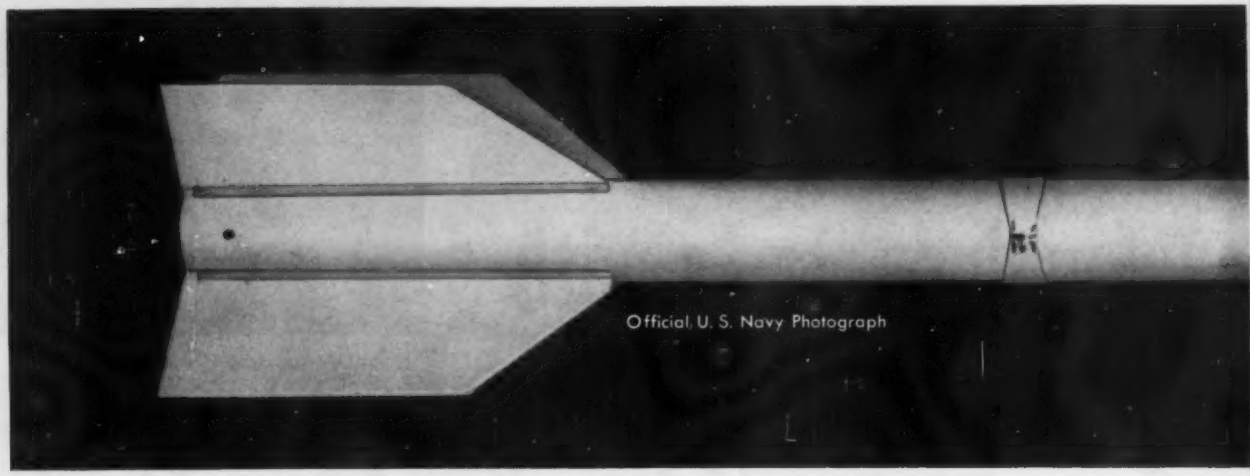
"*Supplier reliability is important*"—F. V. Hanaway, manager of purchases, Talon, Inc. Here Mr. Hanaway, center, talks steel with Sharon salesman Gordon Garrett and Talon steel buyer Carl Parson.

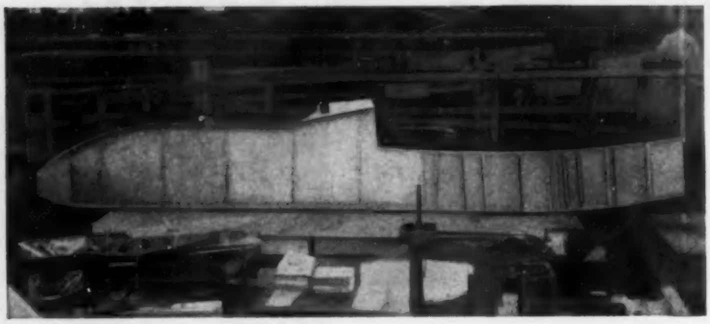
PHOTOS BY KARSH OF OTTAWA

"*Steel quality dictates design*"—Thane E. Hawkins, chief engineer, Shu-Lok Fastener Division.

SHARON *Quality* STEEL

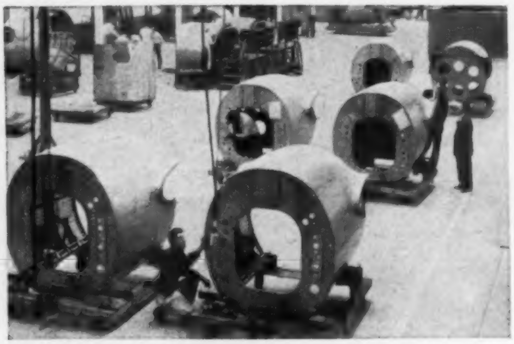
SHARONSTEEL





REPUBLIC TITANIUM is used in dozens of structural components and details in the Martin P6M SeaMaster, including engine nacelle center beams such as the one illustrated. Commercially pure titanium and titanium alloys supplied by Republic increase strength and heat resistance, reduce weight. Republic Titanium Alloys are among the strongest produced, offer exceptionally high strength values at elevated temperatures.

REPUBLIC'S NEW, TYPE HS6460 METAL POWDER is ideal for sinterings of highly stressed components in aircraft and missiles. Provides minimum tensile strength of 60,000 psi at 6.4 density as sintered . . . 100,000 psi after heat treatment. Less than .004% shrinkage from die size at 6.4 density. Available in quantities up to and including 12 tons or multiples. Can be used with existing operating equipment. Mail coupon for technical data sheet.

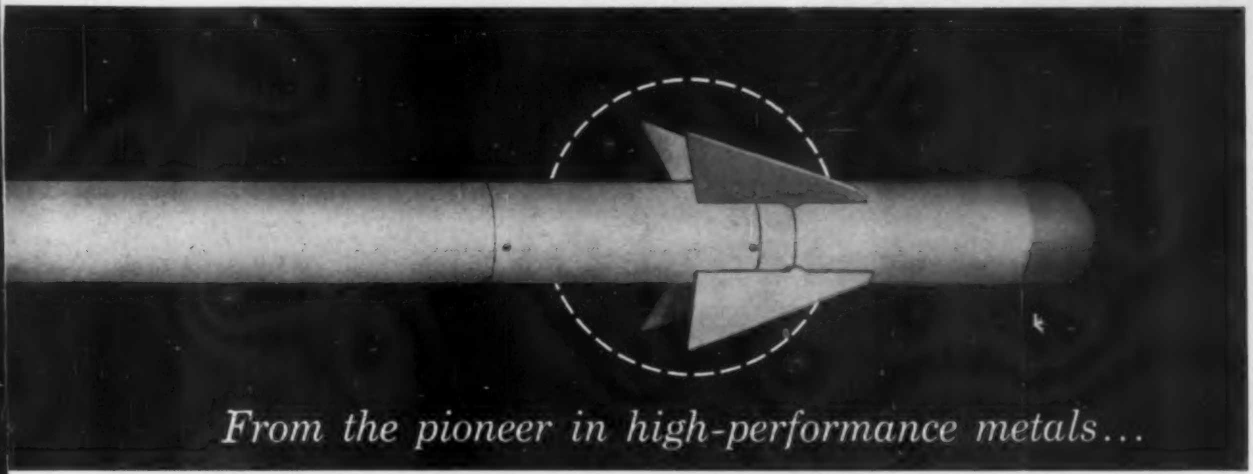


REPUBLIC ENDURO® STAINLESS STEELS—types 301 and 302—are currently being used by Solar Aircraft Company in the fabrication of complete engine nacelles for Navy P2V patrol bombers. Stainless construction offers greater strength, permits use of lighter gages, increases corrosion and high temperature resistance. All types are readily formed into desired shapes by the usual commercial methods. Send coupon for complete information.

REPUBLIC

REPUBLIC STEEL

World's Largest Producer of Missile Metals—Titanium,



TYPE 4130 ALLOY STEEL FINS FOR THE SIDEWINDER

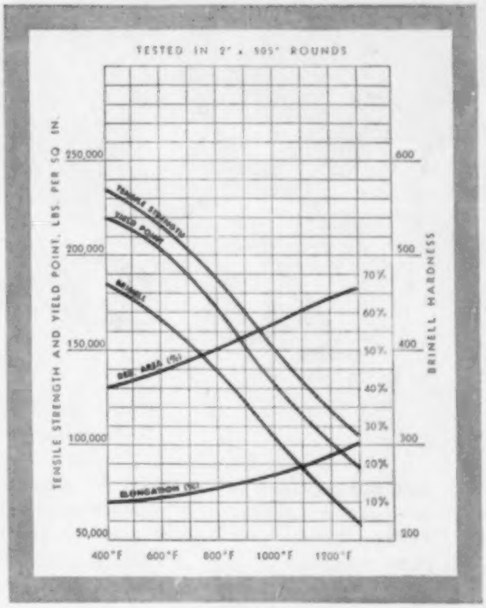
Close-tolerance, delicately contoured fins for the Sidewinder air-to-air missile are currently being produced from Republic Type 4130 Alloy Steel by the Storms Drop Forging Company, Springfield, Massachusetts. Choice of this high-strength alloy, according to Storms, was dictated by extreme performance requirements.

Republic 4130 offers exceptionally high strength-to-weight ratios with the highest strength values. As seen at right, tensile strength in the heat-treated condition is over 230,000 psi after tempering at 400°F., with a Brinell Hardness of 460. Uniform response to heat treatment assures complete deep-hardening penetration.

The Storms Drop Forging Company reports no production difficulties involved in the use of Republic 4130. Fins are produced from hot-rolled 1½" diameter 4130 bars in successive forging, hot trimming, grinding, wet tumbling, and coining operations.

Republic has pioneered in the development and production of new metals to resist heat, reduce weight, or increase strength. With constantly expanding research as well as production facilities and capabilities, Republic stands as the nation's largest producer of ***high-performance*** metals—titanium, stainless, and alloy steels.

Let us help you find the most advantageous use of these metals in *your* project. Return the coupon for complete information without obligation. Please indicate if you would like a Republic Metallurgical Specialist to call.



TYPE 4130

REPUBLIC STEEL CORPORATION
DEPT. MP-7817
1441 REPUBLIC BUILDING • CLEVELAND 1, OHIO

Have a metallurgist call:	Send more information on:
☐ Alloy Steel	☐ Alloy Steel
☐ HS6460 Metal Powder	☐ HS6460 Metal Powder
☐ Stainless Steel	☐ Stainless Steel
☐ Titanium	☐ Titanium

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Company________________________

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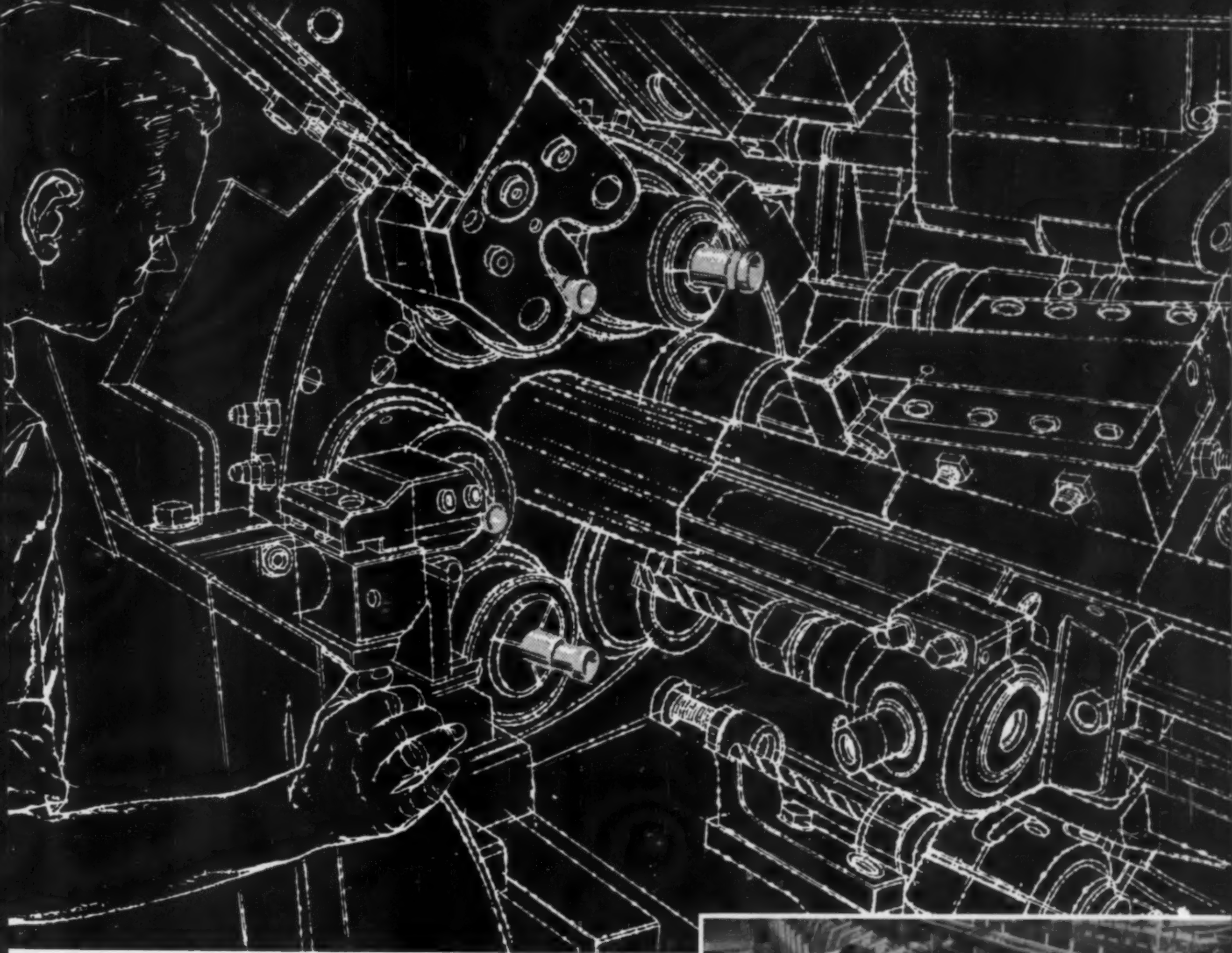
City____________ Zone____ State______

STEEL

Stainless Steel, and Alloy Steel



The Ultimate Test

The ultimate test of quality in stainless steel bars takes place in screw machine production, where every bar is literally cut to pieces.

The Perry-Fay Company, Elyria, Ohio, a leader in screw machine production, has been subjecting J&L bars to this demanding production-line test for more than a year, **without a single failure, without a single reject.** Perry-Fay reports: "We consistently get superior surface finish, closer tolerances, fully formed rolled threads with J&L stainless bars."

Whether you need stainless steel bar stock for high-speed, high-production operations, or a single bar for extraordinary requirements, turn to J&L. J&L leads the industry in melt shop standards for stainless steel, the point where quality starts—and new production profits begin.

Careful attention to every production detail is the key to J&L quality.

J&L

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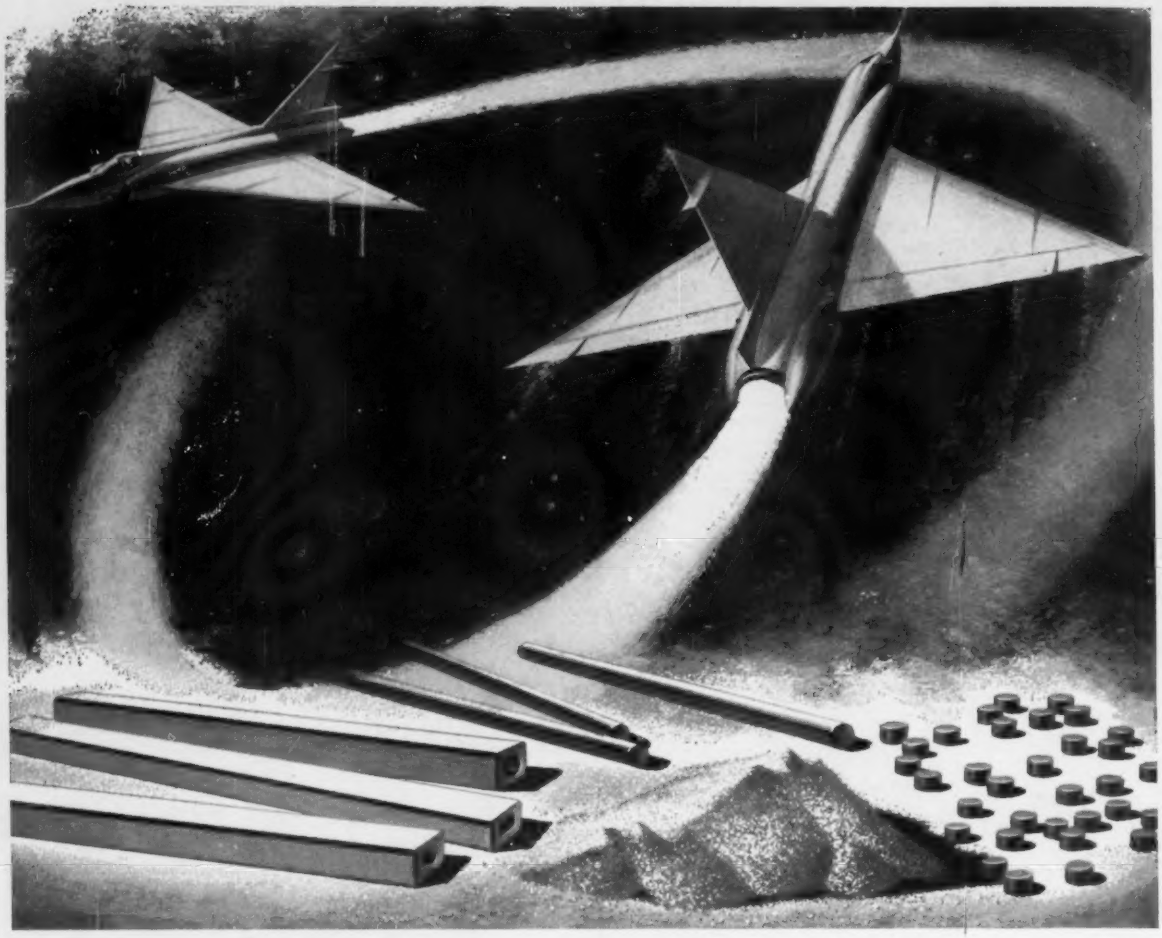

Sylvania Tungsten and Molybdenum...

All forms for better high-temperature alloys

Custom-made Sylvania Tungsten and Molybdenum pellets, powder, ingots and electrodes are helping leading metals producers meet and beat today's tough requirements for high-temperature alloys. Their precise composition and unmatched purity permit the most exacting specifications to be met easily and quickly.

Here are some of the important ways Sylvania Tungsten and Molybdenum are being used in the development of new and better high-temperature metals:

- POWDER FOR CARBIDE MANUFACTURE
- POWDER FOR SLIP CASTING
- PELLETS FOR VACUUM MELTING
- ELECTRODES FOR ARC CASTINGS
- INGOTS FOR FORGING

If any of these forms offer the right solution to your problem, Sylvania can supply the exact purity and composition you need. Contact your Sylvania representative, or the Chemical & Metallurgical Div. in Towanda, Pa. We will be glad to discuss your high-temperature metal needs with you.

SYLVANIA
Subsidiary of
GENERAL TELEPHONE & ELECTRONICS

SYLVANIA ELECTRIC PRODUCTS INC.
Chemical & Metallurgical Div.
Towanda, Penna.

Big Paul digs and dumps 105 tons in 50 seconds!

USS "T-1" and TRI-TEN Steels cut dead weight—boost strength

Even from a 100-foot-high perch, the mammoth size of the bucket of Big Paul, the King of Spades, is hard to comprehend.

There are three of these 70-yard giants—all built by Marion Power Shovel Company. All achieve strength and toughness with least weight by the use of USS "T-1" Constructional Alloy Steel and USS TRI-TEN High-Strength Low-Alloy Steel.

Big Paul sets the pace at the Peabody Coal Company's River King mine near Freeburg, Illinois. It rams through rock and shale to uncover some two million tons of coal per year.

Since 1950, the art of big shovel making has increased dipper size from 35 to 45, 55, 60, and now 70 cubic yards per bite. Most of the buckets and dipper sticks of these giant shovels are made of USS "T-1" Steel, for otherwise, it would be almost impossible to make them light enough and tough enough. They hold up in this service, taking terrific impact abrasion and shock loading, even in the dead of winter. This is possible because USS "T-1" Steel retains its toughness at temperatures far below zero.

Dipper Size Increased 25%

USS "T-1" Steel has often enabled a boost in the capacity of original equipment without increasing weight. For example, a 20-yard bucket was replaced with a 24-yard "T-1" Steel job. Other dippers were boosted from 26 yards to 32, and 36 yards to 45—increases of 25%.

Many other parts—dipper stick, bail handles and crowd rack—are built stronger and lighter with this 90,000 psi minimum yield strength constructional alloy steel. (USS "T-1" Steel plates up to 2½ inches thick inclusive are *now* available with a minimum yield strength of 100,000 psi.)

The booms and A-frames of most shovels over 45 yards are designed with high-strength low-alloy steels with 50,000 minimum yield point . . . usually USS TRI-TEN Steel.

Perhaps you need a steel that offers higher yield strength, extraordinary toughness and resistance to impact abrasion, combined with relative ease of fabrication. USS "T-1" Steel is your answer, and we'll gladly help you adapt it to your application. For free booklet, write United States Steel, 525 William Penn Place, Pittsburgh 30, Pennsylvania.

USS, "T-1" and TRI-TEN are registered trademarks

◀ 70-yard dipper and handle, crowd rack, bail and sheave blocks—all built stronger and lighter with USS "T-1" Steel.

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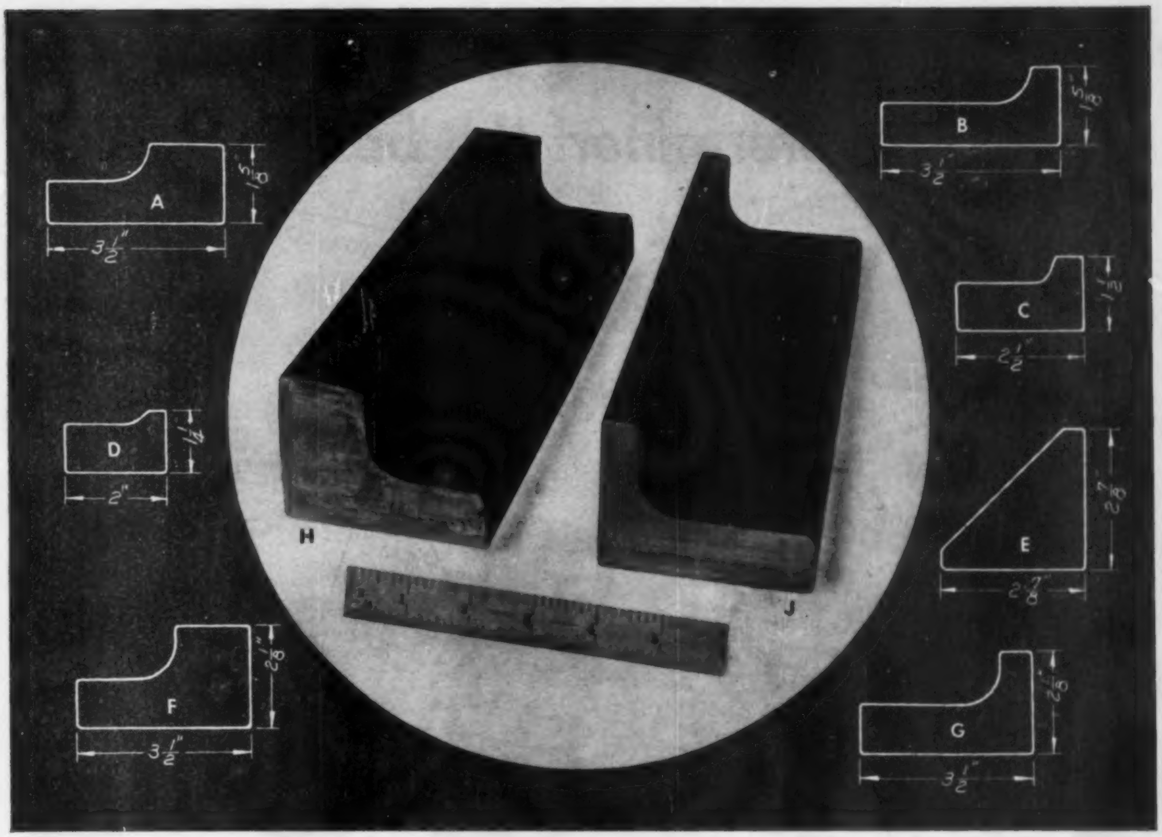
Columbia-Geneva Steel – San Francisco
Tennessee Coal & Iron – Fairfield, Alabama
United States Steel Supply – Steel Service Centers
United States Steel Export Company

United States Steel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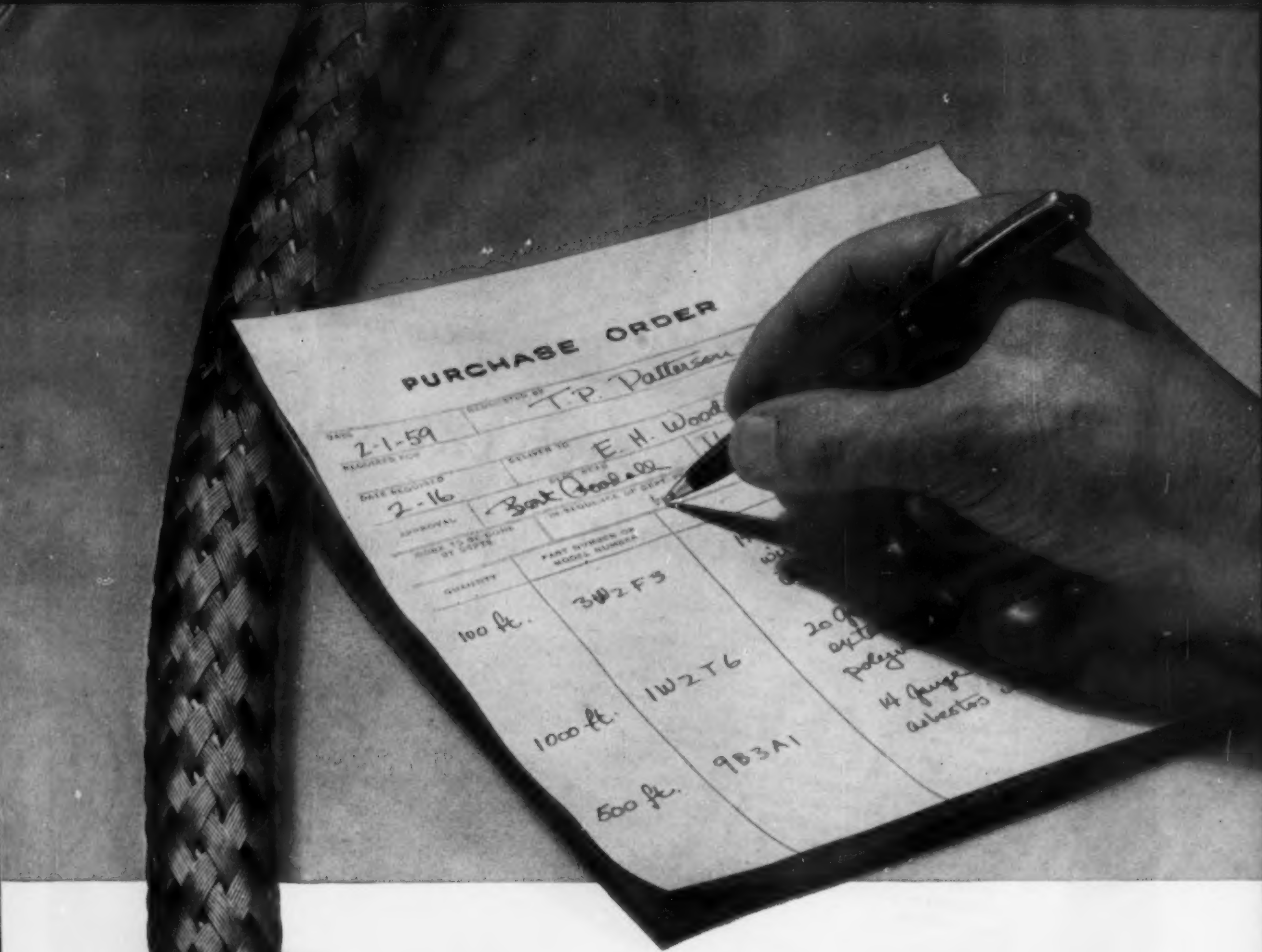

Write your own ticket for Honeywell thermocouple wire

Choose from over 100 variations of insulated thermocouple wire and thermocouple extension wire. Honeywell can supply it from stock, with insulation in any of the conventional combinations of asbestos, glass, polyvinyl, Teflon and others. Should your application require other than conventional insulation, Honeywell can custom-make what you need, quickly and economically.

Call your local Honeywell field engineer . . . he's as near as your phone. Or write for Buyer's Guide C100-8.

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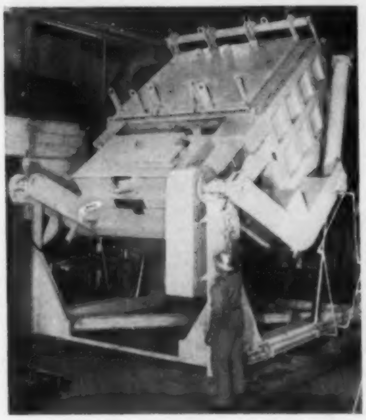
Honeywell

First in Control

APPLICATION and EQUIPMENT new products

Induction Holding Furnace

A new 30,000-lb. aluminum induction holding furnace has been announced by the Melting Furnace Div., Lindberg Engineering Co. It has a



three-section cover that is hydraulically operated. Chamber lining is of monolithic construction and is nonwettable to aluminum. Tilting mechanism has positive fingertip control. Pouring lip is located in the axis of tilting providing a constant pouring arc regardless of the furnace tilt. The furnace is 17 ft., 6 in. long by 15 ft. wide by 10 ft. high and weighs 75,000 lb.

For further information circle No. 250 on literature request card, page 48-D.

Oxygen Analysis

The Hays Corp. has announced a new analyzer specifically developed for measurement of low concentrations of oxygen. It is available in three different ranges: 0 to 1%, 0 to 2%, 0 to 3%. The analyzer is not affected by hydrogen concentrations up to 50%, is sensitive to changes of as little as 0.01% in oxygen content and is accurate to ±2% of range. The hydrogen insensitivity makes the unit applicable for oxygen measurement in inert gas atmospheres and other high hydrocarbon mixtures. The Model 632 utilizes the concept that oxygen and a few other relatively uncommon gases are paramagnetic. The analyzer incorporates a basic Wheatstone bridge resistance circuit within a recorder to provide a continuous record of oxygen content by measuring variations in the paramagnetic properties of the sample gas.

For further information circle No. 251 on literature request card, page 48-D.

Colored Finish

Conversion Chemical Corp. has announced a colored finish for some nonferrous metals for identification, sales appeal and corrosion resistance. Colors range from pastels to dark shades and black depending on the metal being processed and the type of chromate film chosen. Zinc, zinc die castings, cadmium, brass, copper, aluminum and silver may be treated by this process although best results are with zinc.

For further information circle No. 252 on literature request card, page 48-D.

Continuous Casting

New high-production semicontinuous casting equipment for extrusion of copper billets at Halstead Metal Products, Inc., has been announced by Lobeck Casting Processes. The new casting installation consists of two semi-

continuous casting machines mounted in tandem and fed with liquid metal from an electric arc furnace. Designed to turn out extrusion billets of phosphorus deoxidized copper at a rate of up to 6 tons per hour, the two machines each produce two 7-in. diam. by 12 ft. long billets.

For further information circle No. 253 on literature request card, page 48-D.

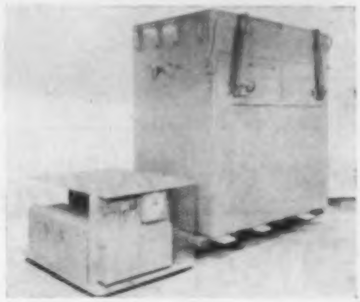
Contact Alloy

Bridgeport Brass Co. has announced a special bronze alloy for use in electrical contacts. Contact bronze is similar to phosphor bronze in performance, yet costs up to 25% less. Strips of this alloy can be formed without sacrifice of spring properties. Contact bronze contains 89% Cu, 8.95% Zn, 1.90% Sn and 0.15% P. The phosphorus helps impart spring properties to hard rolled tempers.

For further information circle No. 254 on literature request card, page 48-D.

Cold Treatment

Cincinnati Sub Zero Products has announced the development of a new very low temperature line of refriger-



ation equipment. The model pictured operates to −120° F. The over-all dimensions of the cabinet are 92 in. high by 58 in. wide by 94 in. long. Only 38 in. of the height is above floor level, the balance of the chamber being recessed into a foundation pit. Automatic operation of dual lids is provided by airlift cylinders. The refrigeration system is powered by 3 and 5 hp. accessible hermetic motor compressors. The chamber is designed for use with convection fluid to facilitate chilling of large parts. Thermal capacity provides for cooling 500 lb. of steel every 8 hr. from +70 to −120° F.

For further information circle No. 255 on literature request card, page 48-D.

Beryllium Wire

The Brush Beryllium Co. has announced the successful drawing of pure beryllium wire under laboratory conditions. Using standard wire drawing equipment and specially

Cutting back the Thermal Thicket

Solving high-temperature problems through research is part of Haynes Stellite's complete metallurgical services. This metallograph is used to observe metals at 2200 deg. F.

The great strength and high scaling resistance of HAYNES alloys at temperatures of 2000+ deg. F. are providing long service life in the hottest areas of jet engines. Flame holders, flame steps and afterburners are some of the hot spots where the properties of HAYNES high-temperature alloys are helping combat burnout, erosion, and stress in the jet, ramjet, missile, and rocket fields.

There are twelve HAYNES high-temperature alloys to choose from, formulated to handle virtually any heat condition. Among them: HASTELLOY alloy X with remarkable resistance to oxidation up to 2200 deg. F. HAYNES alloy No. 25 that resists stresses, oxidation, and carburization up to 2000 deg. F. And HASTELLOY alloy R-235, outstanding in the 1500 to 1750 deg. F. range. All are readily available.

HAYNES
ALLOYS
HAYNES STELLITE COMPANY
Division of Union Carbide Corporation
Kokomo, Indiana

UNION CARBIDE

Address inquiries to Haynes Stellite Company, 420 Lexington Avenue, New York 17, N. Y.

designed preheat furnace, 0.090-in. wire has been successfully drawn from 0.250-in. rod. The ultimate objectives of this project are to produce wire of good mechanical properties and to develop further basic information on the working and heat treatment of beryllium. The most critical variables in beryllium wire drawing appear to be drawing temperature, die design, crystallography, and the use of proper starting material.
For further information circle No. 256 on literature request card, page 48-D.

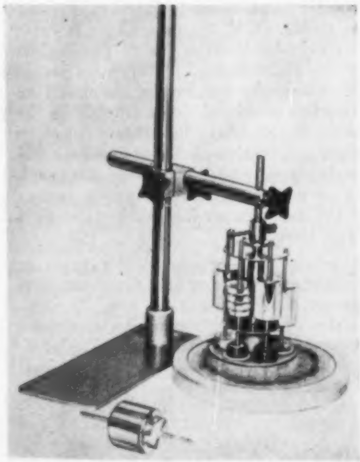
Heat Treat Basket

A new heat treat basket weighing less than 5 lb. per square foot of surface and featuring a looped-wire

crossrod construction has been announced by Bix Co. It was designed for a high strength to weight ratio and has considerable open area.
For further information circle No. 257 on literature request card, page 48-D.

Specimen Grinding Fixture

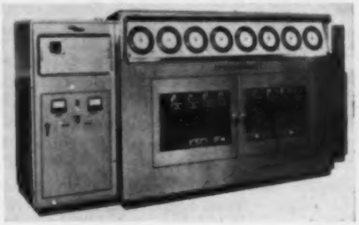
William J. Hacker & Co. has announced metallographic specimen holders which accommodate up to six specimens simultaneously. By means of adapters, specimens of different



diameter can be processed at the same time. The specimens processed are inserted in the holder without clamping and can be removed during the work. To assure that the relative movement of both the disk and the specimens is always correct, a liquid brake has been introduced to retard the movement created by the friction between the disk and the specimens.
For further information circle No. 258 on literature request card, page 48-D.

Spectrometer

Baird-Atomic, Inc., has announced a re-engineered and improved direct reading spectrometer to allow a



greater number of elements to be analyzed at one time. The chemical composition of metal samples can be determined in less than 1 min. with the results presented in per cent concentration on indicator dials. The Spectromet can be installed close to the melt shop or production floor. An automatic optical servomonitoring system continually compensates for variations in temperature and atmospheric pressure as well as the effects of shock or vibration.
For further information circle No. 259 on literature request card, page 48-D.

Test Furnace

A gas-fired furnace for laboratory and research use has been announced by Hirt Combustion Engineers. Originally developed to determine thermocouple reliability at temperatures above 3000° F., the furnace features specially designed burners that require no water cooling and use a standard 16-oz. blower. Operating temperatures of the furnace range from 2000 to 4300° F. Heating chamber is 6 in. in diameter and 6 in. high, but the size can be varied to meet specific requirements.

Furnace operation is started with a preheat burner which raises cavity temperature slowly to 1000° F. to avoid thermal shock to refractories. The main burner operating on a lean air-gas mixture raises the furnace temperature to 1800° F. Then preheated air from the cavity is added to the normal fuel mixture to raise the temperature at the rate of 700° F. per hour. At 3800° F., the fuel mixture is enriched with oxygen to pro-

ACHESON

dispersions digest

Reporting uses for

dag® BRAND DISPERSIONS

COLLOIDAL DISPERSIONS OF GRAPHITE, MOLYBDENUM DISULFIDE, AND OTHER SOLIDS

'dag' and 'Prodag' are trademarks registered in the U. S. Patent Office by Acheson Industries, Inc.

MUELLER BRASS SAVES $15,000 A YEAR ON FORGING LUBRICATION

Efficiencies realized by just one company — with the help of Acheson Dispersions — have already added up to this substantial savings. Uniform coverage, easy sprayability, and lasting lubrication effectiveness are providing this leading forgings producer: longer die life, increased production, fewer rejects, and improved forgings. This lubricating success story is being repeated throughout the metal working industry. Possibly *you* could profit from the use of an Acheson Dispersion.

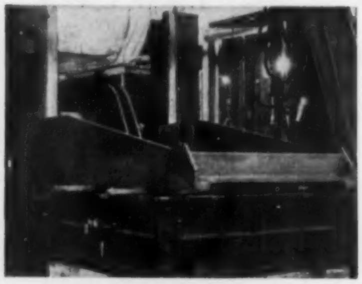
'Prodag' application on forging presses at Mueller Brass Company has saved between $15,000 and $17,000 annually for the past fifteen years. These impressive savings earned by this Port Huron, Michigan company—the world's largest producer of brass and bronze forgings — have been realized in many areas.

Previously, crank forging pressmen at Mueller swabbed the dies between each press stroke. Mueller designed their own spray apparatus, both manual and automatic, to lubricate lower and upper dies simultaneously. Time studies have shown that spraying has effected a five percent-per-pound economy over the swab method.

Spray application of 'Prodag' at Mueller Brass Company has resulted in impressive production savings.

Even more importantly, by using Acheson's 'Prodag' — a dispersion of graphite and water — diluted 1:35, Mueller has gained longer die life, reduced the percentage of scrap loss, and has obtained a better finish on their forgings. According to Mr. O. M. Hanton, Chief Forging Engineer for Mueller, "with 'Prodag' we get the right amount of lubricant on the die. Swabbing resulted in too much lubrication at one place or another in the die cavity, resulting in either a ruptured die or a defective part. Previously, every forging produced had to go to the grinding department. And grinding is one of the most expensive operations in a forge shop."

In producing deep-cavity forgings, or products which demand much smaller tolerances, Mueller uses 'dag' No. 3 — another of Acheson's graphite-water base dispersions. If you have a forging lubrication problem it will pay you to call in your Acheson Service Engineer or write for Bulletin No. 426.



'dag' 35, brush-applied to the slides of this rollover machine, increases machine life for this midwest foundry.

An expensive foundry problem was solved for the D. J. Murray Manufacturing Company, Wausau, Wisconsin, with the use of Acheson's 'dag' 35 — colloidal graphite in an alkyd resin solution. Slides on the huge rollover machine installed in their foundry division, previously lubricated by first a dry graphite and then rosin, were becoming deeply scored as a result of its 90-cycle-a-day operation in the handling of bench and floor molds.

The scoring and machine vibration was so severe that according to Maintenance Foreman, Ben Sayles, "we could see that the life of the machine was going to be very short if we continued this method of lubrication." Coating the slides daily with 'dag' 35, improved machine operation immediately. The scoring all but disappeared. After two years of application with this Acheson dispersion, no repairs have been necessary and none are foreseen. Since the entire production of their grey iron sand slinger line — some 60 tons of material in 8 hours — goes through this machine, the downtime avoided represents an important savings to the company.

For additional information, write for Acheson Bulletin No. 425. Address Dept. MP-89.

ACHESON *Colloids Company*

PORT HURON, MICHIGAN

A division of Acheson Industries, Inc.

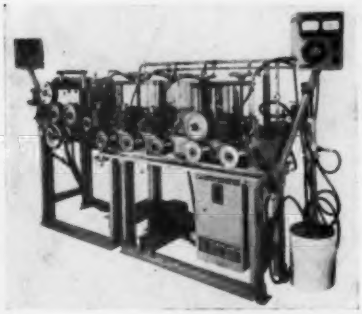
Also Acheson Industries (Europe) Ltd. and affiliates, London, England

Offices in: Boston • Chicago • Cleveland • Dayton • Detroit • Los Angeles • Milwaukee
New York • Philadelphia • Pittsburgh • Rochester • St. Louis

duce temperatures to 4300° F. Gas, preheated air, and oxygen are automatically proportioned.
For further information circle No. 260 on literature request card, page 48-D.

Bar and Tube Marker

Jas. H. Matthews & Co. has announced a combination surface conditioner and bar and tube marker to prepare tubing for acceptance of offset printed marking and indented marking. As the material to be marked enters the power driven guide rolls, a series of solvent bearing spray nozzles and adjustable squeegees remove any drawing compound that would affect the quality of the subsequent marking from the tube surface. Opposite the offset printed mark, the incisor portion of the unit provides indented marking. The unit is adjustable for bar and tube sizes from ¼ to 6 in. and is adjustable for marking speeds from 125 to 1000 ft. per min.



For further information circle No. 261 on literature request card, page 48-D.

Bonding Mortar

A new refractory bonding mortar has been announced by Harbison-Walker Refractories Co. Ankorite 65 has been used to bond blast furnace bottom blocks and linings, electric furnace roofs, and malleable and air furnace side walls and bottoms. A recent settling test shows that Ankorite 65 remains in suspension longer than other types of bonding mortar.
For further information circle No. 262 on literature request card, page 48-D.

Leaded Steel Tubing

Seamless leaded C1020 carbon steel tubing in sizes from 0.012 to 1⅛ in. O.D. has been announced by Superior Tube Co. The addition of 0.15 to 0.35% Pb to C1020 increases the machinability from 72 to 85 or 90% and the cutting speeds from 120 to 140 or 150 s.f.m. There is virtually no difference in mechanical properties between leaded and nonleaded C1020.
For further information circle No. 263 on literature request card, page 48-D.

Cleaner

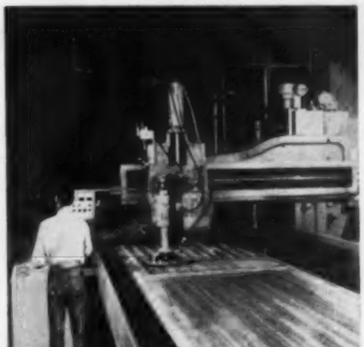
A new acidic detergent for cleaning, smut removing, and prepaint conditioning has been announced by Oakite Products, Inc. It can be used as a precleaner to improve phosphate coatings and also to clean brass, aluminum, zinc, and terne plate. The compound is recommended for use in spray washing machines, in a three-stage operation: clean and condition with Compound No. 86, 2% by volume in water solution; overflowing rinse; and final acid rinse. It may also be used in tank immersion operations.
For further information circle No. 264 on literature request card, page 48-D.

Vacuum Cabinets

General Vacuum Corp. has announced its Series 600 vacuum cabinets for moisture-free and dust-free storage of in-process electronic parts. Complete assemblies of 2 to 8 cabinets have controls and a single vacuum pump. Each system has automatic controls for opening of any cabinet, and automatic evacuation on closing. Inside dimensions provide for eight trays of parts, each tray 12 by 18 in.
For further information circle No. 265 on literature request card, page 48-D.

Grinding

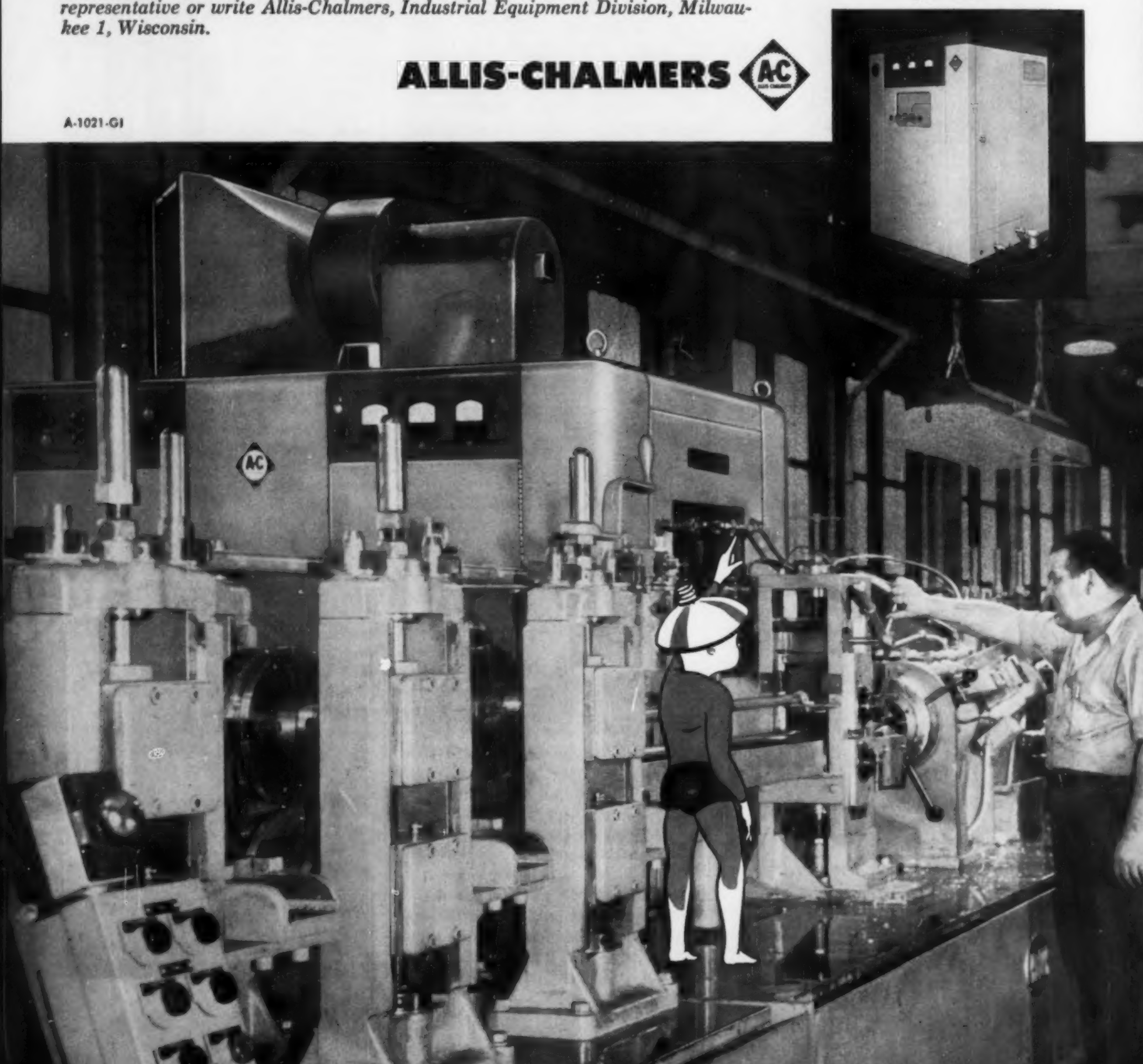
A new large automatic machine for the precision grinding of resistance welded honeycomb cores has been announced by Swedlow, Inc. The device will accommodate honeycomb core blankets up to 5 by 20 ft. in size and machine the faces of such blankets to thickness tolerances of ±0.003 in.



For further information Circle No. 266 on literature request card, page 48-D.

Tensile Tester

A new vertical bench-mounted tensile tester, capable of performing compression tests, has been developed by Steel City Testing Machines, Inc. A



1/6-hp. motor and a small hydraulic pump supply pressure to the hydraulic cylinder located behind the hydraulic load gage at the top of the tester. Loading is controlled by a manual valve. Capacity of the tester is 10,000 lb. The lower jaw holder is adjustable to three positions by sliding it in and

out of three pairs of slots in the side rails. The tester can accommodate any length of specimen up to 7 in. Model TE-10 is supplied with one set of jaws and a motor wired for 110-volt, single-phase, 60-cycle a. c.

For further information circle No. 267 on literature request card, page 48-D.

Controllers

New instruments that indicate, record and control any process variable convertible to voltage or resistance change have recently been announced by Thermo Electric Co., Inc. Applications include conductivity, flow, humidity, pressure and temperature measurement. Instrument accuracy is guaranteed to ±0.25% of scale or 5

microvolts. Interchangeable scale ranges are available and can be installed in the field. Reference junction compensating resistors may also be changed when converting from one thermocouple calibration to another. Basic control action is two position (off-on) but can be adapted to three-position control to lag or lead the control set-point over the entire range of the instrument.

For further information circle No. 268 on literature request card, page 48-D.

Aluminum Tube

General-purpose seamless aluminum tube has been announced by Chase Brass & Copper Co. Produced in many diameters and wall thicknesses, the tube is made from 3003-O aluminum alloy in soft temper. Sizes range from ⅛-in. O.D. with a wall thickness of 0.025 in. having a safe bursting pressure of 1066 psi., to ¾-in. O.D. with wall thickness of 0.049 in. having a bursting pressure of 348 psi.

For further information circle No. 269 on literature request card, page 48-D.

Electroplaters' Microscope

Bausch & Lomb Optical Co. has announced a new electroplaters' microscope designed for on-the-spot measurements of plating thickness. The microscope has Balcoted optics for maximum light transmission, and one-

micron divisions on the fine adjustment knob. Filar micrometer eyepiece includes a movable hair actuated by a micrometer screw with a drum graduated in 100 divisions. Each division on the drum represents 0.00001 in. on the specimen when the 40-power objective is used. The eyepiece also includes a fixed scale to facilitate counting the revolutions of the drum. A heavy stand cancels out vibrations caused by nearby machinery and other sources of shock or vibration.

For further information circle No. 270 on literature request card, page 48-D.

Melting Furnace

A new dry-hearth furnace for melting electrical quality aluminum has been announced by Selas Corp. Both dry and wet sections of the furnace are roof-fired with Duradiant burners that eliminate direct flame impinge-

ment, avoid contamination of the aluminum and provide close control of heat input. A special lining in the furnace also minimizes contaminations. All melting is accomplished in the melting zone and the metal flows to the holding section.
For further information circle No. 271 on literature request card, page 48-D.

Drawing Lubricant

Climax Molybdenum Co. has announced the use of molybdenum disulphide as a lubricant in drawing Type 430 stainless steel wire. A thin protective layer prevents metal to metal contact between the wire and the draw dies and improves die life. From 5 to 20% MoS_2 is combined with a soap drawing compound. To remove the lubricant from the finished wire, the wire is electrolytically cleaned in an anodic process.
For further information circle No. 272 on literature request card, page 48-D.

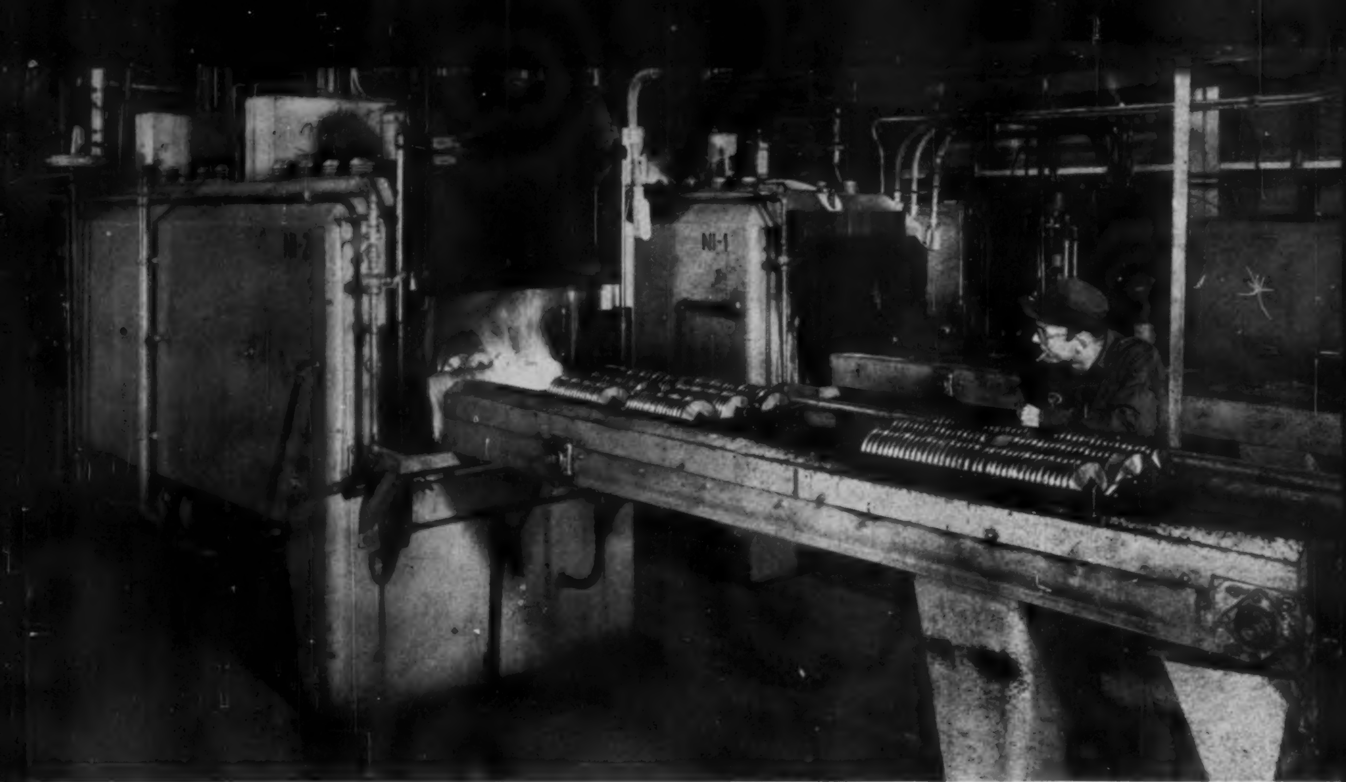
Hardness Tester

Riehle Testing Machines Div. has announced a portable Rockwell hardness tester designed for on-the-job testing of materials, tools or pieces. Readings may be taken at any angle

and no setup time is required. This tester weighs 3 lb., 6 oz. and uses standard indenters and loads. Large dial markings in red and black identify Rockwell scales.
For further information circle No. 273 on literature request card, page 48-D.

Copper Brightener

Allied Research Products, Inc., has announced the introduction of a new copper addition agent for cyanide plating solutions. Isobrite 623 can be used in solutions for either semibright or bright plating. It is suitable in either rack or barrel plating and is easily controlled. Over steel, zinc die castings, brass or bronze parts, Isobrite 623 produces a copper film that can be bright nickel plated without the need for buffing if the finish of the original material is good enough.
For further information circle No. 274 on literature request card, page 48-D.



Two of six Ipsen Heat Treating Units used in Perfection's two Chicagoland plants

"...with Ipsen heat treating units, we get bright work, and increase production per man-hour."

Perfection Tool and Metal Heat Treating Co.

Don Petersen is president of Perfection Tool and Metal Heat Treating Company, one of Chicago's largest and best known custom heat treating organizations. To learn firsthand how and why Perfection uses semi-automated, controlled atmosphere, heat treating equipment, we had an interesting chat with Mr. Petersen. Here are his answers to our questions:

Q. Since 1951 you have purchased a number of Ipsen "straight-through" heat treating units. Why have you favored this equipment?

A. We were well pleased with the first Ipsen furnace we bought, and our customers were well satisfied with the quality of the work that came out of it. Since the end of World War II, there has been a much greater demand for atmosphere work, and, as this demand increased, we have purchased additional furnaces. We have four Ipsen units in our Hubbard Street plant . . . and two in our branch plant in Lombard, Illinois. All six units have two work chambers which make them ideal for preheating.

Q. What kind of work do you handle in your Ipsen equipment?

A. In the course of the average day we handle many, many different types of work . . . gears, screw machine parts, stampings, etc. We use your furnaces for carburizing, carbonitriding, neutral atmosphere hardening, and carbon restoration. The versatility of Ipsen furnaces is quite a selling point as far as we are concerned.

Q. Have you been able to increase production with this equipment?

A. Yes. With Ipsen equipment we have substantially increased production per man-hour. One reason for this is that quenching is automatic . . . and our operators do not have to handle parts in and out of the quench by hand.

Q. Apparently you like the automatic quench feature. Why?

A. Definitely. The automatic timing makes it easy to duplicate previous quenching results. We eliminate the element of human error in quenching.

Q. What about maintenance of your Ipsen equipment?

A. You have an excellent record on this count. We find that your equipment requires very little maintenance.

Q. What do your men think of Ipsen equipment?

A. Our men like your equipment because it's cleaner, cooler, and easier to operate. It takes less effort per pound of work treated.

Q. Has Ipsen equipment permitted you economy of floor space?

A. Yes. We find your equipment to be quite compact for the amount of work handled. In our Hubbard Street plant four Ipsen units are placed so the discharge ends converge on the same washing and degreasing unit. The entire installation occupies only 600 sq ft of floor space.

A brochure describing the type of Ipsen equipment used in the Perfection plants is available. Ask for your copy.

AUTOMATIC **Ipsen** HEAT-TREATING UNITS

IPSEN INDUSTRIES, INC. • 723 S. MAIN STREET • ROCKFORD, ILLINOIS


for "everything on earth"
—and into space
Superior STRIP STEELS
stainless • alloy • high carbon • boron
stainless • zirconium and its alloys
Space metals—specified for vital areas of our rockets, missiles, and superspeed aircraft. Here is where exactness in manufacture counts for most —where know-how such as SUPERIOR's assures the utmost precision in strip steel grade, gauge, temper and finish. ● Whether your needs are up in the air or right down to earth, SUPERIOR can serve you dependably. Check with us!
Superior Steel Division
OF
COPPERWELD STEEL COMPANY
CARNEGIE, PENNSYLVANIA
For Export: Copperweld Steel International Company, New York

Twin Disc Clutch Company

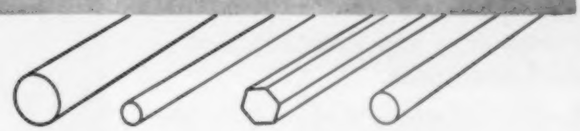
ELIMINATES HEAT TREATING FURNACES

by using

STRESSPROOF

with copper

STEEL BARS



In Racine, Wisconsin, Twin Disc Clutch Co. saved money on a plant addition by eliminating heat treating furnaces . . . and they continue to save on part costs by using a material which needs no heat treatment . . . STRESSPROOF.

On the strength of over 15 years' experience with STRESSPROOF, Twin Disc knew they could cut their costs by purchasing this material which has the necessary properties in the bar.

They produce about 150 different models of power take-off shafts . . . see cross-section drawing. These shafts must possess great toughness and have the strength to take heavy loads. They must resist wear at the journals. Because one end of each shaft must be machined to individual customer specifications, machinability is important. Warpage after machining cannot be tolerated.

STRESSPROOF with copper fills these requirements on all counts because it has these four qualities in the bar: (1) Strength without heat treating. (2) Machinability (copper further improves machinability). (3) Excellent resistance to wear. (4) Minimum warpage.

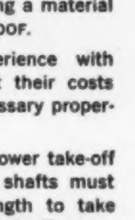
By using STRESSPROOF, Twin Disc eliminates the cost of heat treating, cleaning and straightening. Working conditions are better . . . the plant is cleaner and cooler, and floor space requirements are less. Time and money consuming production steps are eliminated.

Twin Disc gets better parts at lower cost, and perhaps you can profit by their experience. Unless you have investigated STRESSPROOF recently, you may be overlooking worthwhile savings, especially since copper has now been added to improve machinability.

Available from your Steel Service Center.

La Salle STEEL COMPANY

1424 150th Street, Hammond, Indiana



Please send literature describing La Salle STRESSPROOF with copper.

name__________

title__________

company__________

address__________

city__________ zone_____ state_____

APPLICATION and EQUIPMENT new literature

276. Alloy Castings
Data folders on two types of alloy steel castings. Composition, properties, hardenability bands, uses. *Unitcast*

277. Alloy Powder
New bulletin gives technical data on alloy powder HS 6460 including properties, specifications and heat treating recommendations. *Republic Steel*

278. Aluminum
8-page bulletin on aluminum casting alloys. Properties; selection of casting method; pig, ingot and billet compositions. *Metals Div., Olin Mathieson Chemical*

279. Aluminum Bronze
8-page booklet on study that led to development of one-piece, nickel-aluminum bronze ship propeller. *International Nickel Co.*

280. Aluminum Die Castings
Bulletin on design and manufacture of aluminum die castings. *Hoover Co.*

281. Aluminum Extrusions
Folder lists alloys used, finishes, trade phraseology. *General Extrusions*

282. Aluminum Finish
Bulletin on new invisible finish for aluminum describes Alodine No. 1000 and includes flow sheet for immersion process. *Amchem Products*

283. Arc Welders
New bulletin on operating features, construction details and applications of a new line of manual arc welding machines. *Lincoln Electric Co.*

284. Atmosphere Control
8-page Bulletin SC-178 on furnaces, atmosphere equipment, controls for bright annealing, hardening and tempering, batch annealing, age hardening and carburizing. *Surface Combustion*

285. Atmosphere Furnace
12-page bulletin 1054 on electric furnaces with atmosphere control for hardening high speed steel. *Sentry*

286. Atmosphere Heat Treating
Hydrogen and protective atmosphere heat treating of some stainless, heat resisting, beryllium and nickel alloys in Ferrotherm Newsletter. *Ferrotherm Co.*

287. Austempering
Bulletin No. 167 on mechanized salt bath installation for continuous heat treatment of farm tools. *Ajax Electric*

288. Billet Casting
8-page bulletin describing quality control of billet and slab casting of aluminum alloys. *Lobeck Casting*

289. Bimetal Applications
44-page booklet, "Successful Applications of Thermostatic Bimetal", contains uses, formulas, calculations. *W. M. Chace*

290. Blast Cleaning
Complete information on Malleabrasive for cleaning and finishing. *Globe Steel Abrasive*

291. Blast Cleaning
16-page bulletin No. 705 describes line of heavy-duty barrel cleaning equipment, dimensions, specifications. *Pangborn Corp.*

292. Bolts
16-page booklet on high-strength bolting for structural joints includes ASTM specifications covering this bolting material. *Bethlehem Steel*

293. Boron Stainless
8-page booklet on composition, structure, corrosion resistance, welding and mechanical properties of 1% boron stainless steel. *Superior Steel*

294. Brass Alloys
New 6-page bulletin on importance of grain size in brass alloys. How grain size or average crystal diameter is affected by annealing and cold rolling. *Bridgeport Brass Co.*

295. Brazing
16-page reprint on furnace brazing gives advantages of method, design factors and methods of handling assemblies and furnaces for brazing. *Electric Furnace*

296. Burners
Buzzer Catalog No. 1570 describes industrial gas burners, furnaces and accessories for heat treating, metal melting, soldering and drying. *Charles A. Hones*

297. Burners
Bulletin 48.32 on flat flame gas burners. Characteristics, applications. *North American Mfg.*

298. Carbide Tools
New 40-page Catalog MT-059 gives data and prices for blanks, solid carbide indexable inserts, other tools. *Willey's Carbide Tool Co.*

299. Carbon Brick
Bulletin on properties, grades, applications of carbon and graphite brick for handling corrosive chemicals and molten metals. *National Carbon*

300. Carbon Potential Controller
Information sheet on instrument for use with endothermic gas generators and controlled atmosphere furnaces. *Rolock*

301. Castings
12-page bulletin on ArmaSteel castings. Properties, applications, machinability and heat treating. *Central Foundry Div.*

302. Castings
Brochure on plaster mold castings of brass, bronze, aluminum, beryllium copper. *Ohio Precision Castings, Inc.*

303. Chromium Plating
4-page bulletin on new "crack-free" chromium plating process. *Metal & Thermit*

304. Clad Metals
New 8-page bulletin on five-layer copper-cored Aliron and three-layer copper-base Aliron for rectifier anodes. Advantages, properties. *General Plate Div.*

305. Cleaning
Bulletin No. 72 gives reagents and procedure for acid acceptance test for trichlorethylene. *Hooker Chemical*

306. Cleaning
4-page bulletin on washing machines. Design, special features, dimensions. *Waukee Engineering Co.*

307. Coatings
4-page catalog on heat-proof protective coatings. Basic types, applications, methods of applying and temperature ranges. *Markal Co.*

275. Welding Aluminum

The welding of aluminum by the gas-shielded metal-arc and tungsten inert-gas methods are discussed in this 120-page spiral-bound book. Topics covered are weldability of aluminum and aluminum alloys, selection of the best process for the particular application, equipment and techniques, safety practices. Illustrations are plen-

tiful and picture such things as effect of joint design on gas flow, electrode extension for various types of joint, basic joint designs. A series of tables give specifications for various types of welds in plate of different thickness. *Air Reduction Sales*

308. Cold Header
Bulletin on solid die double stroke cold header. Design features. Advantages of toggle-type construction for actuating heading gate. *Waterbury Farrel Foundry & Machine*

309. Controlled Atmospheres
Bulletin No. 2051 on Dewpointer. Models, specifications, principle of operation, application. *Illinois Testing Lab.*

310. Controllers
Data on controllers and recorders. *Samuels Sons Iron & Steel Co.*

311. Controllers
16-page Bulletin No. 9 gives data, operation diagrams, schematic drawings of capacitrols. *Wheelco*

312. Conveyor Belts
Report on service life of woven wire conveyor belts operating at temperatures of 2050° F. *Cambridge Wire Cloth Co.*

313. Copper Alloys
24-page manual on alloys in rod form. Typical parts. Specifications covering alloys described. *Mueller Brass*

314. Copper Plating
8-page Technical Brochure describes CuSol plating process, applications, equipment and prices. *Seymour Mfg. Co.*

315. Corrosion of Copper
32-page reference booklet to aid in selecting copper alloy best suited for particular corrosive condition. 187 applications. *American Brass Co.*

316. Cutting Fluid
4-page folder on the development of coolants from water to oil to chemical coolants containing no petroleum. Description of Hocut 237. *E. F. Houghton*

317. Cutting Oil
Bulletin 39 on transparent cutting oil which is designed for use on a wide variety of steels. *Sun Oil Co.*

318. Decarburization
8-page booklet on effects of decarburization on tool steels tells what it is and what can be done about it. *Carpenter Steel*

319. Degreasers
Catalog No. 10M 359 on standard and special vapor degreasers and industrial ovens. *Baron Industries*

320. Degreasers
Folder on vapor and solvent degreasers describes equipment and advantages. *Randall Mfg.*

321. Degreasing
Booklet on vapor degreasing. Design, installation, operation and maintenance of equipment. *Circo Equipment*

322. Die Steel
Data sheet on Huron high-carbon, high-chromium die steel. Applications, forging, annealing, hardening, tempering, properties. *Allegheny Ludlum*

323. Electric Furnaces
Data sheet describes and gives specifications of standard nonmetallic resistor furnaces. *Harrop Electric Furnace Div.*

324. Electroplating
Chart gives reference data for gold, rhodium, palladium, platinum, silver, nickel plating. *Technic*

325. Electropolisher
Metal Digest, Vol. 1, No. 5 gives theory and practice of electrolytic polishing of metallurgical samples and describes electropolisher. *Buehler, Ltd.*

326. Environmental Testing
New 12-page Catalog No. 59 on altitude, temperature, sand and dust test chambers, models, specifications. *American Research*

327. Ferroalloys
Folder on ferrocolumbium additions to steel and high-temperature alloys, analyses and advantages. *Union Carbide Metals*

328. Finishing
Guide for determining cost of finishing compares finishing in the production shop, finishing at a job shop and use of prefinished metals. *Apollo Metal Works*

329. Finishing Processes
30-page catalog describes types and processes of finishing. Machines, accessories, applications. *Roto-Finish Co.*

330. Flame Hardening
Publication No. M-2015 on precision flame hardening machine with automatic operation. Specifications, design. *Cincinnati Milling Machine Co.*

331. Flame Hardening
Bulletin tells how flame hardening improves rolls. Chart shows ranges, depth of hardness. *Detroit Flame Hardening*

332. Force Measurement
New booklet on modern industrial techniques for measuring force, weight, pressure. Advantages of electronic force measurement. Principles of SR-4 bonded strain gages and use in force measurement devices. *Baldwin-Lima-Hamilton*

333. Forging
Brochure on Cameron forging process. *Cameron Iron Works*

334. Forgings
12-page booklet on how forged weldless rings and flanges are made. Case histories. *Standard Steel Works Div., B-L-H*

335. Forgings
Folder on facilities for production of flat-die forged products. Electronic equipment used. *Smith-Armstrong*

336. Formed Shapes
Catalog No. 1053 describing numerous formed shapes made from ferrous and nonferrous metals. *Roll Formed Products*

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Data on chest for use down to −140° F. for production and testing. *Revco*

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Bulletin 658 on saturable reactor for regulation and control of electric ovens and furnaces. *Sorgel Electric Co.*

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16-page catalog on baskets, trays, fixtures and carburizing boxes for heat treating. 66 designs. *Stanwood*

341. Furnaces
List of used furnaces in stock. *Papesch & Kolstad, Inc.*

342. Furnaces
Data on line of industrial heat treating furnaces including car-bottom, shaker-hearth, box-type and semimuffle. *Denver Fire Clay Co.*

343. Furnaces
Bulletin describes 18 electric furnaces for research and small-scale production, with operating temperatures to 3000° F. *Harper Electric*

344. Furnaces
Bulletin 5902 describes pusher furnaces for temperatures to 2600° F. Data on complete line of furnace types. *C. I. Hayes*

345. Furnaces
Bulletin 858 on carbon-resistor tube furnaces for temperatures to 5000° F. Uses, atmospheres, specifications. *Hevi-Duty Electric Co.*

346. Furnaces
12-page catalog on electric heat treating furnaces. Data on each of 57 models. Controls, instruments, elements and accessories. *Lucifer Furnaces, Inc.*

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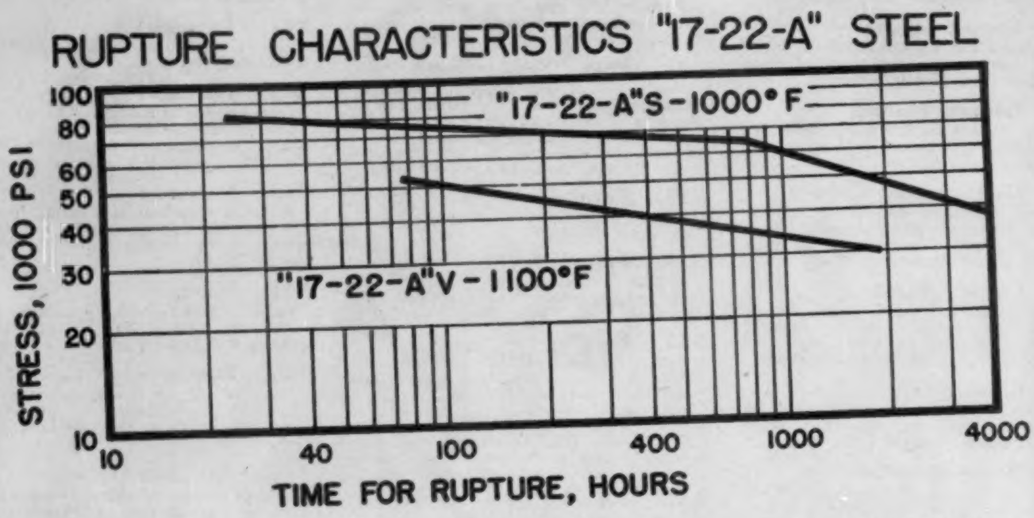
List of industrial furnaces and equipment in stock. *TherMaTek Co.*

348. Hardness Tester
20-page book on hardness testing by Rockwell method. *Clark Instrument*



Stress-rupture curves show strength of "17-22-A" (S) at 1000° F and "17-22-A" (V) at 1100° F.

How to solve high temperature parts problems with low alloy steels

HERE'S how you can solve the problem of using expensive, high alloy steels for missile engine parts, airplane brakes, gas turbines or other units that must operate at high temperatures. You can use the Timken Company's *low* alloy "17-22-A"® steels. They contain less than 3% alloy. Yet they give *high* alloy performance—with maximum strength up to 1100° F. You save strategic alloys, cut your costs.

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Catalog 72-1 on Leitz miniload tester for Vickers and Knoop hardness tests. *Opto-Metric Tools, Inc.*

350. Hardness Tester
Bulletin S-33 on vertical-scale and dial-indicating scleroscopes. How they are calibrated. *Shore Instrument*

351. Hardness Tester
Bulletin TT-59 on tester for measuring standard Rockwell and superficial hardness. *Wilson Mechanical Instrument*

352. Hardness Tester
20-page booklet on Rockwell superficial hardness testers shows models, accessories, applications. *Wilson Mechanical Instrument*

353. Hardness Testers
Folder on portable hardness testers for testing of various sizes, shapes and types of metal. *Newage Industries*

354. Hardness Testing
Bulletin A-18 on Alpha Co. Brinell hardness testing machines. *Gries Ind.*

355. Heat Exchanger
Bulletin 124 describes 30-million Btu. heat exchanger, giving uses and descriptions. *Niagara Blower Co.*

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12-page brochure on titanium-carbide alloys for high-temperature service. Properties, applications. *Kennametal*

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16-page bulletin on design, foundry practice and applications. *Electro-Alloys*

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4-page bulletin on a home study and in-plant course on heat treatment of steel. *ASM Metals Engineering Institute*

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369. High-Alloy Castings
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High Frequency Heating Review, Vol. 1, No. 5, on induction brazing and soldering. Review of new equipment. *Lepel High Frequency Laboratories*

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Folder on manganese-copper steels. Properties, fabricating practice. *Republic Steel*

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87-page book on factors affecting high-temperature properties. 45 pages of data on tensile, creep and rupture properties of 21 high-temperature steels. *U.S. Steel*

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Folder describing new spark testing standard for identification of tool steels and surface conditions. *GLD Products Co.*

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Folder R-61 on induction furnace for electric melting and holding of aluminum. *Ajax Engineering Corp.*

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12-page Bulletin 12B6430B on high-frequency induction heating. Specifications, applications, accessories. *Allis-Chalmers*

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12-page Bulletin HF-58-6 on high frequency induction heating equipment. Heat treating, annealing, brazing, forging, shrink fitting data. *Magnethermic*

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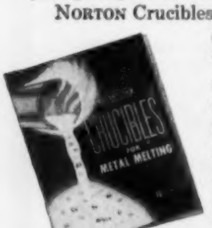
NORTON Crucibles can increase the precision, efficiency and economy of your casting operations. They're available in a wide variety of sizes. Get full details from your NORTON representative. And write for this new informative catalog on the *complete* line of NORTON Crucibles. NORTON COMPANY, Refractories Division, 327 New Bond Street, Worcester 6, Massachusetts.



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Widely used for melting steels and ferrous alloys as well as cobalt, chrome, copper, bronzes and nickel.

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New 4-page Bulletin F-9 on magnetic method and equipment for locating invisible defects in ferrous metal parts and assemblies. *Ferro Machine and Tool*

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Bulletin on Spotcheck dye-penetrant inspection. Advantages, prices. *Magnaflux*

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16-page booklet on magnetic particle inspection. Equipment, uses, kinds of defects that can be found. *Magnaflux*

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Data on ultrasonic inspection and thickness measurement service in field or laboratory. *Sperry Products*

390. Investment Casting
"Pointing the Way" presents seven case histories on advantages of investment castings. *Engineered Precision Casting*

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8-page bulletin describes four cobalt and one iron-base alloy. Properties and recommendations on joining, machining, grinding, heat treating. *Haynes Stellite*

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32-page bulletin on complete line of laboratory balances, balance weights, and accessories. *Harshaw Scientific*

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Bulletin on cutting test specimens describes methods for different types of metals. Price list. *Sieburg Industries*

394. Laboratory Furnace
Data sheet on high-temperature laboratory furnace for operation at 4600° F. for crucible melting. *Zirconium Corp. of America*

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8-page bulletin gives mechanical properties of Rycut 40, medium-carbon fast-machining leaded alloy steel. Case studies. *Ryerson*

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Bulletin 425 on colloidal dispersions for use in metal casting. Best formulas for achieving high lubricity and wetting action. *Acheson Colloids*

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Bulletin 581 on colloidal graphite dispersions for industry. 17 uses listed. Tables on concentrated and ready-to-use solutions. *Graphite Products Corp.*

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4-page Paper X-1 describes a tensile-test machine for evaluation of metalforming lubricants. *Instron Eng. Corp.*

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53-page book on wrought forms of magnesium. Includes 44 tables. *White Metal Rolling & Stamping Corp.*

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New leaflet on manganese alloys gives compositions and uses of ferromanganese briquettes and silicomanganese alloys and briquettes. *Vanadium Corp.*

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Data on Paintstik markers for identification of heat treated parts. *Markal Co.*

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404. Metal Finishing
Literature file on properties and applications of conversion coatings, brighteners, process chemicals and protective coatings. *Allied Research Products*

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Folder on rolling mills, swaging machines, wire shaping mills, wire and tube drawing machines. *Fenn Mfg.*

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Bulletin on all-purpose electric pen which will arc etch any metal. *Newage Industries*

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Data on nondestructive sorting tool for raw, semifinished or finished parts. *J. W. Dice*

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New 8-page brochure on wire, rod and shapes in titanium, zirconium, tantalum, columbium and other special metals. Melting methods and cleaning, rolling, wire straightening techniques. *Johnston & Funk Metallurgical Corp.*

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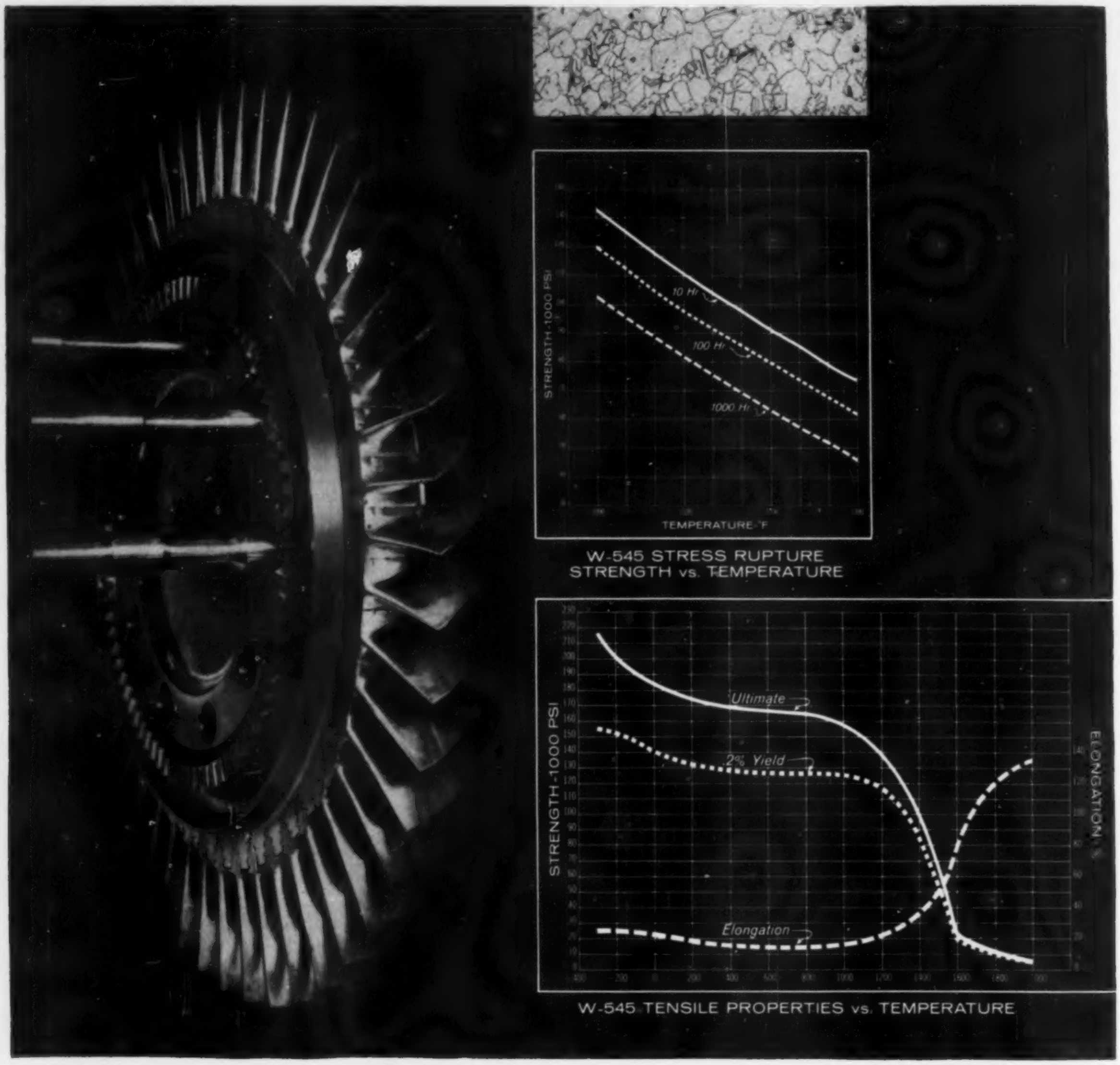
Bulletin on metallograph operated from sitting position. Transitions are instantaneous. Accessories are interchangeable. *Wm. J. Hacker*

(Continued on page 48-A)



NEW HIGH-TEMPERATURE ALLOY W-545 HAS 20% MORE STRENGTH

Twenty percent more strength at 1200°F from this turbine disc gave added dependability for a Westinghouse customer using W-545. This new high-temperature alloy will withstand higher stress levels than similar alloys at the same operating temperatures . . . or it will withstand equivalent stress characteristics at 100°F higher operating temperatures.

Critical high-temperature parts can be made from this material that have excellent strength-to-weight ratios and can be used at temperatures up to 1350°F . . . excellent characteristics at 300°F.

W-545 has proven itself superior for turbine wheels . . . compressor discs and shafts . . . combustion chambers . . . housings and skin materials. W-545 is nonmagnetic and has a low strategic alloy content, permitting ease of fabrication for fasteners . . . rings . . . spacers . . . fittings . . . brackets . . . supports and mounts.

The Westinghouse Metals Plant can furnish strip, sheet, bar, forgings and forging stock in W-545 and other wrought high-temperature alloys. Get all the information today; write: Westinghouse Electric Corporation, Materials Manufacturing Department, Blairsville, Pennsylvania. J-05010

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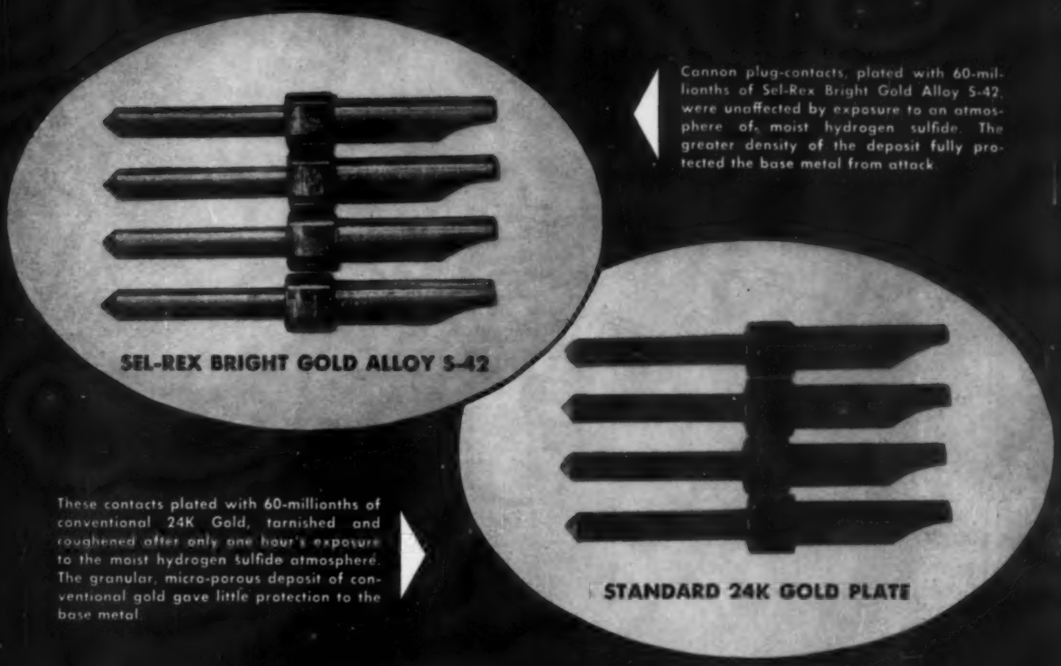
CANNON ELECTRIC improves contact performance with SEL-REX Bright Gold Alloy S-42



Contacts used in world-famous Cannon Plugs must be capable of withstanding corrosion and tarnish, in addition to the punishing effects of repeated engagement and disengagement. The photographs, taken by Cannon in their own laboratory, show why conventional 24K gold plate failed to meet the requirements of this application.

Both samples were plated with 60-millionths of gold over silver plate, and were photographed after an hour's exposure to an atmosphere of moist hydrogen sulfide. The contacts plated with 24K gold tarnished and roughened – those plated with Sel-Rex Bright Gold Alloy S-42 retained their original mirror-bright finish.

Says Cannon Electric Company, Los Angeles: "Our brass contacts plated with Sel-Rex Bright Gold Alloy S-42 offer exceptional protection against both corrosion and friction-wear. Some of the advantages we have demonstrated in our own laboratory, and what they mean to us, follow:

"**1. Greater Hardness:-** Knoop 140-160 for Sel-Rex Bright Gold Alloy S-42, compared to only 40-50 for conventional 24K gold plate.

"**2. Greater Wearability:-** The S-42 deposit is smooth and bright. This, in combination with hardness, means that less force is required to separate the mating halves of the connector . . . less wear, less tendency for galling."

"**3. Improved Reliability:-** Ordinary 24K gold plate is quite granular and exhibits considerable micro-porosity. Tarnish, corrosion of the base metal and early failure in-service of the plated contact is the end result. The Bright Gold Alloy S-42, being a smoother, far more dense deposit, has demonstrated much greater protection against tarnish and corrosion in all the tests we have performed at Cannon.

"At Cannon Electric, Sel-Rex Bright Gold Alloy S-42 has been instrumental in solving wear and tarnish problems encountered in connectors used in aircraft, and intricate missile and electronic components."

The foregoing is just another of our many case histories which prove that: "From Missiles and Rockets to Misses and Lockets – there's a Sel-Rex Precious Metal Plating Process to help you make your product better, more salable."

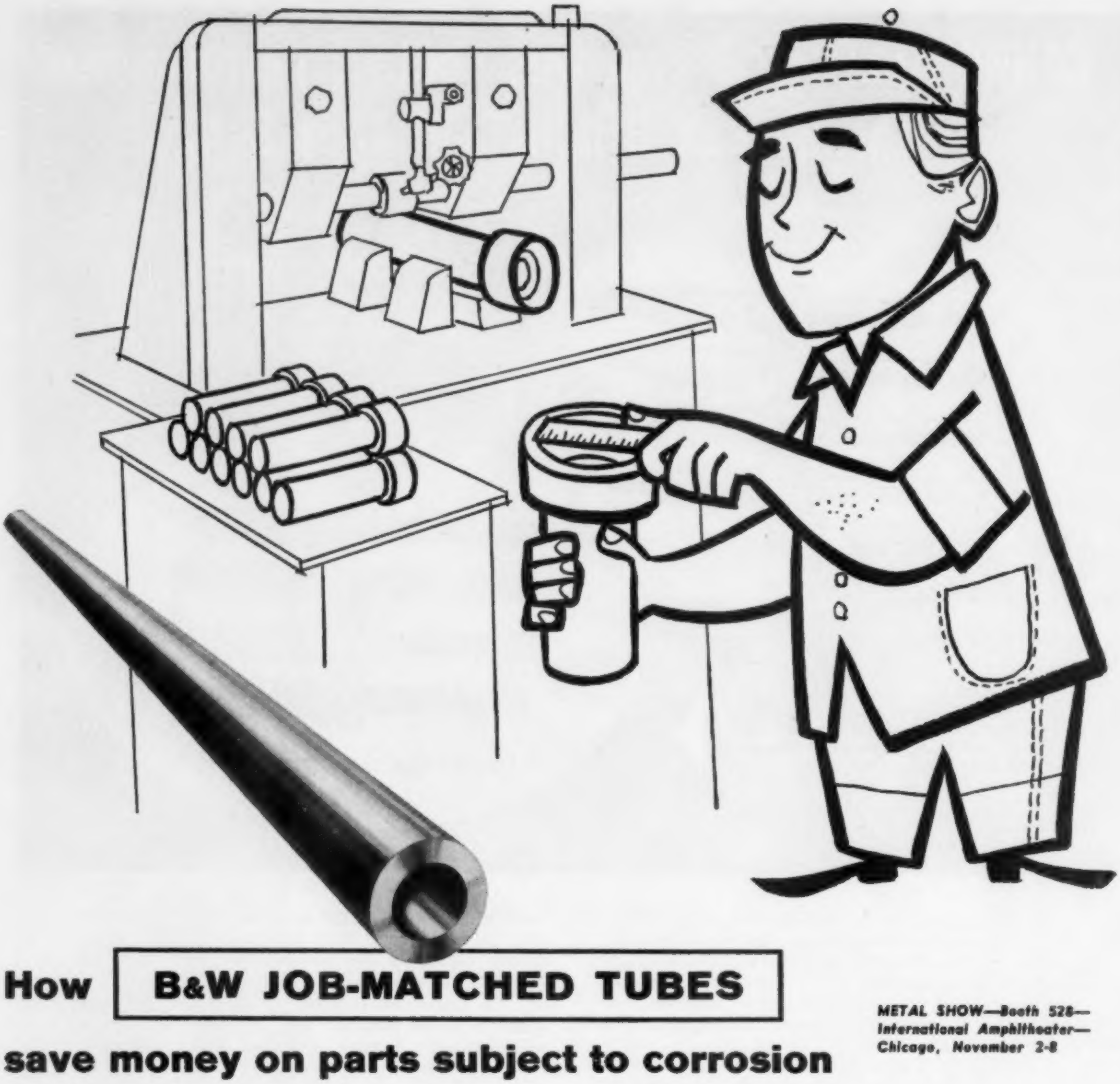
For other case histories, technical information and application data, ask for ML-1.

PRECIOUS METALS DIVISION

SEL-REX CORPORATION

NUTLEY 10, NEW JERSEY

Manufacturers of Exclusive Precious Metals Processes, Metallic Power Rectifiers, Airborne Power Equipment, Liquid Clarification Filters, Metal Finishing Equipment and Supplies.



Superex is easily combined with other insulations such as Johns-Manville Thermobestos®, J-M 85% Magnesia or J-M Insulating Fire Brick.

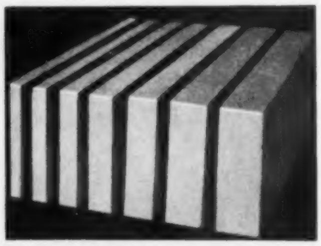
Only Johns-Manville Superex insulation performs 3 ways better at high temperature!

Few industrial products are so outstandingly superior, or so widely used in their area of application, as Johns-Manville Superex® Insulation.

A block insulation formulated of diatomaceous silica and asbestos for furnace and other applications, Johns-Manville Superex brings many advantages to high-temperature service—each contributing to reduced construction, maintenance and operating costs.

Superex is installed with measurable savings in time and labor! It is easy to cut and handle . . . weighs only 2 lbs. per sq. ft. per inch thickness . . . available in a wide variety of large block shapes and sizes. At high temperature—the material's excellent insulating value, thermal stability and resistance to shrinkage keep fuel costs low. Equally important—Superex saves on maintenance, too . . . easily withstands the daily abuse of normal service.

Send for your copy of IN-190A, the 12-page design and technical data brochure. It lists suggested applications—gives complete heat transmission tables and performance data. *Write for it today.* Address Johns-Manville, Box 14, N.Y. 16, N.Y. In Canada, Port Credit, Ont.



Saves waste. Superex comes in 7 standard thicknesses from 1″ to 4″. Other sizes available on order.

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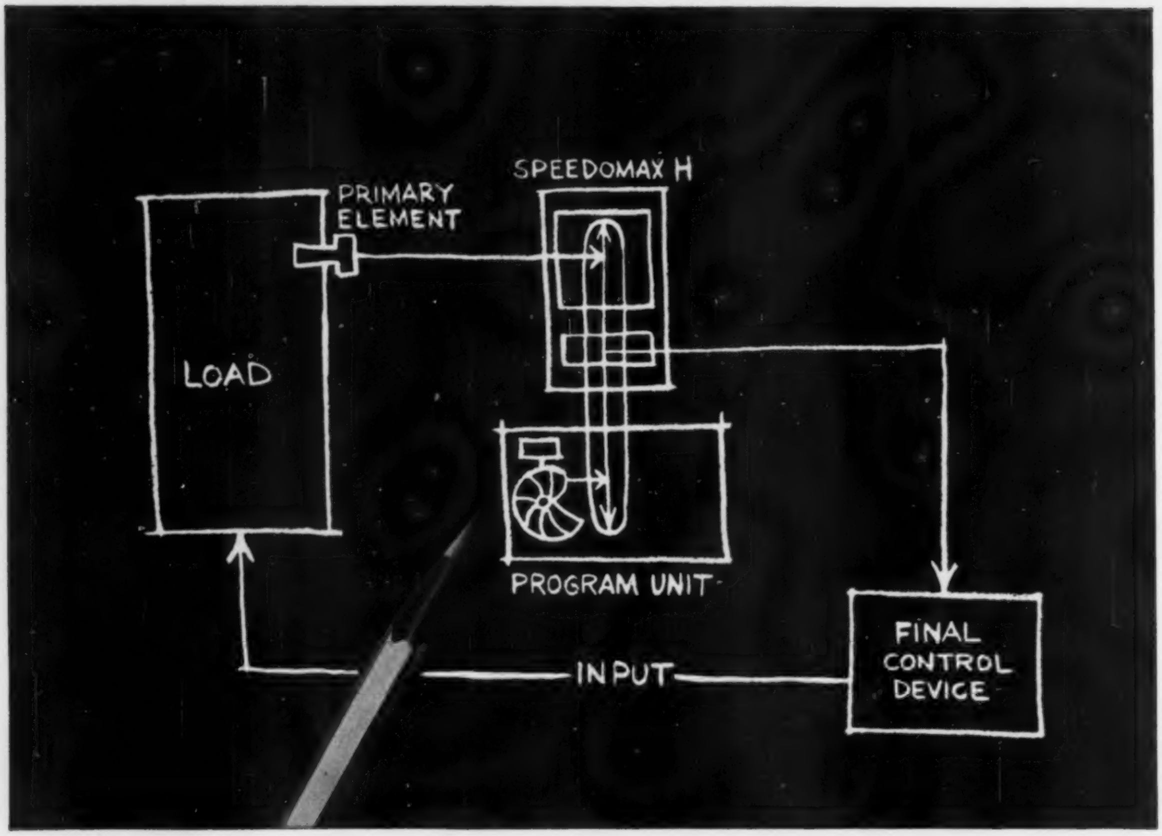

Reproduce your time-temperature cycles exactly with L&N cam-type program control

At the flip of a switch you can heat . . . soak . . . and cool at a preset rate for a preset time with L&N's improved cam type program control! Whether your program is linear or non-linear, this control will continuously regulate input to reproduce *your* cycle . . . again and again.

Heart of the system is the program unit. Essentially it's a motor-operated cam and a control slidewire. The cam is calibrated . . . making it extremely easy to lay out and cut to any time-temperature cycle. Changing a cam to meet a new program takes only a minute. For additional flexibility, the unit has seven standard speeds . . . permitting a multiple number of programs.

Other elements in the control system include a primary element, a Speedomax® recorder and associated control relay, and a final control device. Any change detected by the primary element and measured by the recorder is checked by the program unit, which regulates the final control device to keep the process on cycle.

Also available is a motor-operated front setter type of program control. Recommended for linear programs only, this system offers great flexibility within the range selected.

Both types are available for Two-Position or proportioning control . . . will regulate input to electric or fuel-fired furnaces.

Can your process benefit from programmed heating and cooling? If so, it'll pay you to investigate L&N program control. For more information, call your nearest L&N office, or write 4927 Stenton Ave., Philadelphia 44, Pa. Ask for Data Sheet ND46-33(4).

LEEDS & NORTHRUP
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THE ONES THAT WILL LAST (and last, and last!)? THOSE MADE FROM CONTINUOUS PROCESS ZINC-COATED STEEL SHEETS

And just why will they last and last?

The people of the Galvanized Container Industry, always alert to make improvements to keep their products the best, can give you a multitude of reasons why. Chief among them: the continuous process insures a uniformly applied, corrosion-resistant zinc-coating. In fact, the zinc and steel are integrated to form a tight bond for every square inch, a durable coating which stands up to any rigorous stress of the fabrication process.

Continuous process zinc-coating will not chip or flake, no matter how much it is twisted, crimped or lock seamed. It can be worked to the very limits of the steel itself! Your budget benefits because there is no need for additional coating of any kind.

In continuous process zinc-coated steel, there is a stand-out—Weirkote. On your production lines and in your products, Weirkote will work for you all of the time. For detailed information on the many advantages of Weirkote zinc-coated steel, write today for a brochure. Weirton Steel Company, Dept. S-19, Weirton, West Virginia.

WEIRTON STEEL COMPANY

WEIRTON, WEST VIRGINIA

a division of

NATIONAL STEEL CORPORATION

by Carl F. Joseph
Technical Director

CENTRAL FOUNDRY DIVISION
GENERAL MOTORS
CORPORATION

.....The metallurgy of strength and

The secret of a stronger iron casting lies in the composition, the melting and the heat-treating processes. Perhaps I should use some other word than "secret," because the fact is well known today, but in 1925, when we started our search for a stronger iron, the principle was well known only in respect to steel.

Our research led us to think that heat-treating could improve iron as well. After considerable experimentation, we learned how to arrest the malleablizing process to produce an improved pearlitic malleable iron . . . an iron that compares favorably with the properties of a good grade forged steel. It is from the words "Arrested Malleable iron with Steel-like characteristics" that the name "ArmaSteel" was coined.

The raw materials and melting process for ArmaSteel are very similar to those of our malleable iron . . . the major difference being in the heat-treat cycle. In the cupola, we melt steel scrap, ferrosilicon, and remelt. We add .0025% boron to the charge to assist in breaking down carbides during malleablizing.

Next, the molten iron is tapped into a forehearth where it is desulphurized with soda ash. This removes small particles of slag and impurities, thus improving machinability of the casting. After refining in an electric furnace, the iron is tapped into ladles.

To improve the physical properties on certain castings, .007% bismuth is added as a ladle inoculant: this stabilizes the carbides during the initial freezing of the metal. On heavy castings such as the Pontiac crankshaft, up to .02% bismuth is added. This bismuth-boron combination is a new development.

I mentioned before that the heat-treating of ArmaSteel greatly affected its properties. Actually, we use several different heat-treatments to produce the several ranges of ArmaSteel. All are alike during the malleablizing cycle, where the massive carbides are eliminated. Malleablizing requires about 20 hours: the castings are held at 1750°F. for 10 hours, and near the end of the cycle are dropped to 1650°F., after which they are air-quenched. Brinell hardness at this point is around 300.

Tempering brings the Brinell hardness down to customer's specifications. We produce two standard Brinell ranges of air-quenched and tempered ArmaSteel . . . BHN 197 to 241 (3.9-4.3 mm.), and 163 to 207 (4.2-4.7 mm.). The castings are tempered in a recirculating furnace. The harder material is in the furnace for a total of six hours and forty minutes, and is held at heat for three and one half to four hours at 1270° to 1290°F. The softer material uses the same time cycle but higher heat . . . from 1320° to 1340°F.

For automobile crankshafts, a special hardness range is used. The ArmaSteel is air-quenched and tempered, but the tempering is for six hours at 1200°F., which produces a harder material (BHN 217 to 269).

Two other types of ArmaSteel are produced by reheating the air-quenched castings to 1600°, holding at heat for thirty minutes, then oil-quenching. These are then tempered for three and one half hours at 1170° to 1190°F. BHN is 241 to 269 (3.7-3.9 mm.) and 269 to 302 (3.5-3.7 mm.).

I've gone into detail on heat-treating because it has such a great effect on mechanical properties. Tempering directly controls the amount of combined carbon in the matrix, and this in turn dictates how hard and strong the ArmaSteel will be . . . the higher the combined carbon, the stronger, harder, and less ductile the casting. Thus, the engineer can choose the combination of properties best suited to his application. I can best explain the results of this careful heat-treatment by giving you a brief list of the mechanical properties of ArmaSteel.

1. *Machinability* . . . Because of the carbon nodules in the pearlite matrix, the machinability of ArmaSteel is generally from 10 to 30 percent better than that of steel forgings of the same Brinell. Improvements of up to ten times longer tool life and three times more pieces per machine have been shown.

73-A

2. *Selective Hardening* . . . ArmaSteel responds readily to localized hardening, either by flame or induction methods. A minimum of Rockwell "C" 50 is obtainable on such parts as shifter yokes, rocker arms, and gears. Some applications use the lead immersion or hot salt bath methods, followed by an oil-quench.

3. *Bearing Properties* . . . ArmaSteel is such an efficient bearing material on a hardened steel shaft that bronze bushings are often eliminated. The automotive rocker arm illustrates this excellent non-seizing property in metal-to-metal wear.

4. *High Yield Ratio* . . . The oil-quenched and tempered ArmaSteel has a minimum yield strength of 80,000 psi and ultimate strength of 100,000 psi, making it ideal for highly stressed parts.

5. *Fine Machine Finish* . . . A mirror-like finish can be produced on ArmaSteel. Diesel pistons are an application where this fine finish reduces friction wear to a minimum.

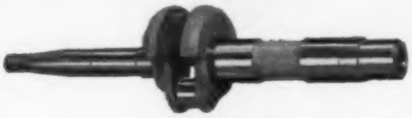
6. *Damping Characteristics* . . . In both small engines and in automotive engines, ArmaSteel crankshafts exhibit a fine damping capacity that aids quiet operation.

7. *Wear Resistance* . . . ArmaSteel withstands excessive wear under heavy loads at high speed.

8. *Fatigue Life* . . . ArmaSteel has good resistance to fatigue, giving maximum endurance and long life.

As countless and varied applications have proven, ArmaSteel is an outstanding engineering material. For information on how your product can benefit from this modern casting metal, write for our "ArmaSteel" catalog.

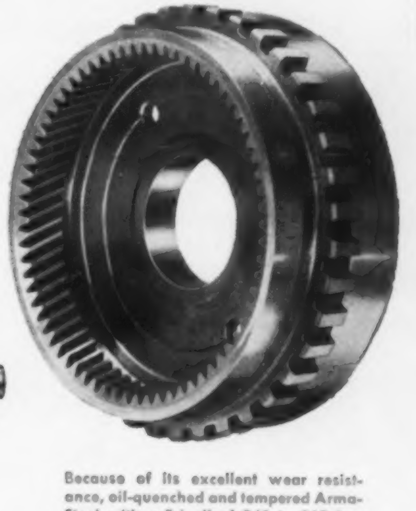
ARMASTEEL® from the standpoint of machinability



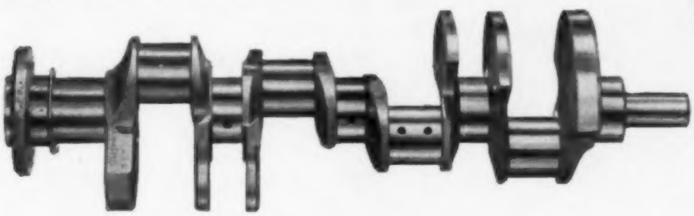
ArmaSteel small horsepower engine crankshafts provide good damping qualities and modest cost due to excellent machinability.

ArmaSteel's adaptability to localized hardening pays off especially well on these automotive rocker arms.

Universal joint yokes of ArmaSteel stand up under severe stresses to same extent as former SAE 1145 or 1151 forgings.



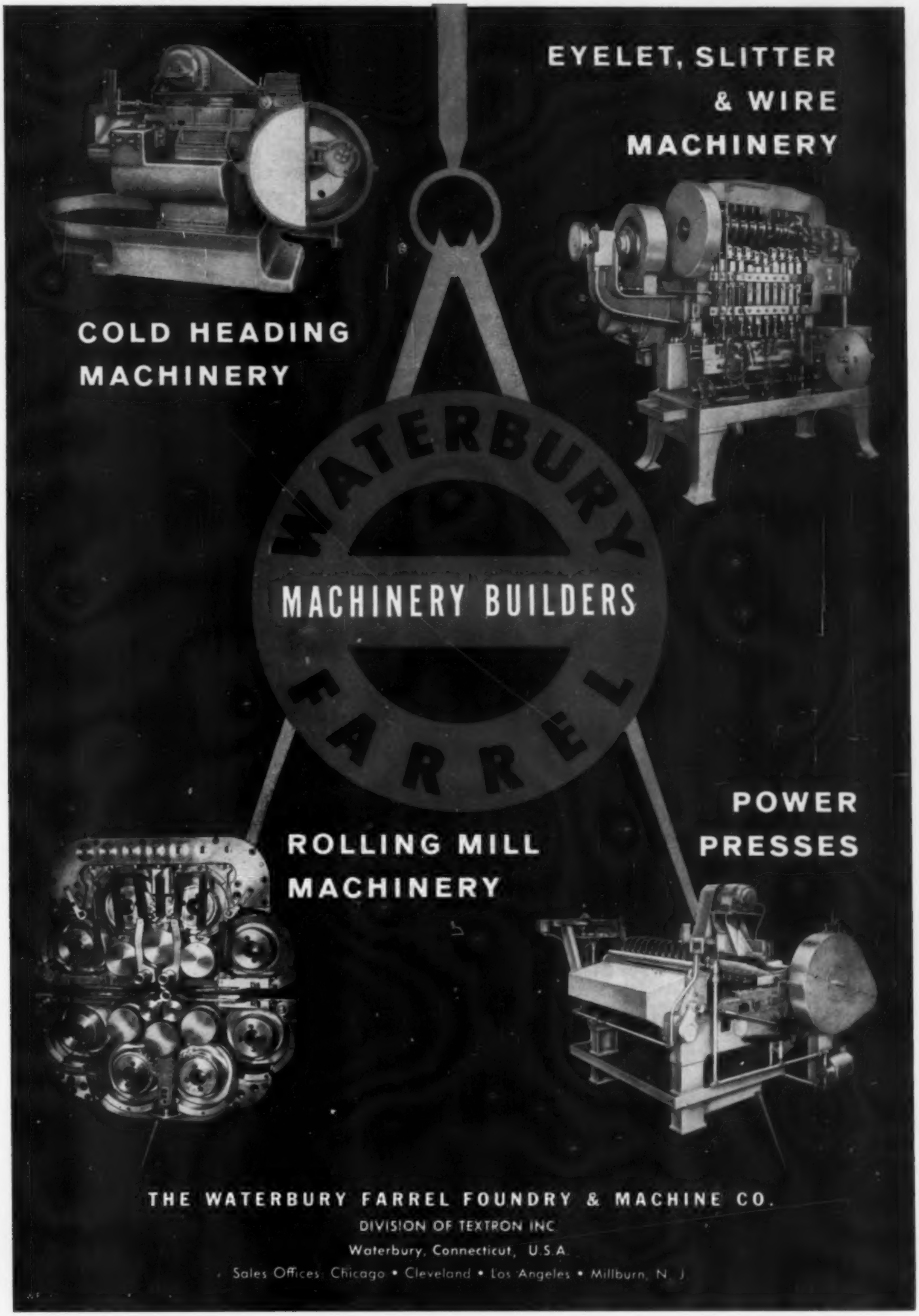
Because of its excellent wear resistance, oil-quenched and tempered ArmaSteel with a Brinell of 241 to 269 has replaced an SAE steel forging for this automotive reverse internal gear.



Pontiac's conversion to ArmaSteel Crankshafts doubled cutter life and speeded up by 50% the grinding of main journals.

CENTRAL FOUNDRY DIVISION

GENERAL MOTORS CORPORATION • SAGINAW, MICHIGAN • DEPT. 19



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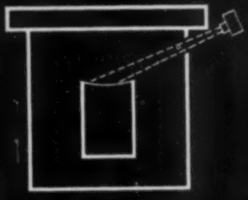

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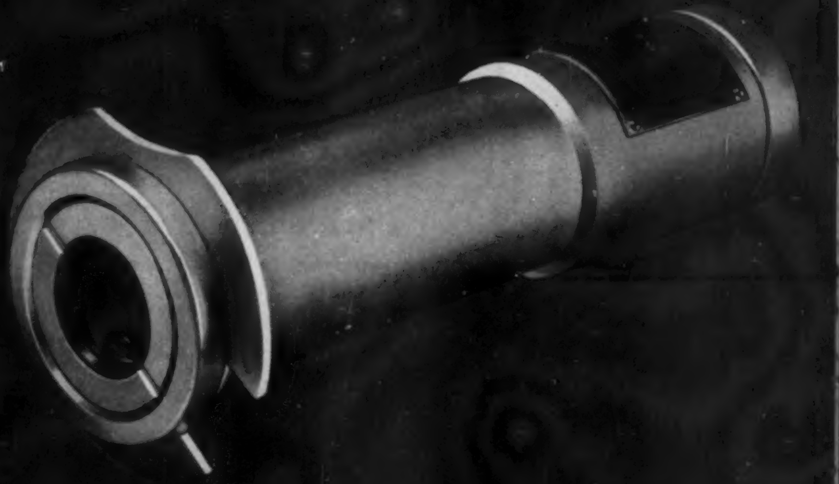

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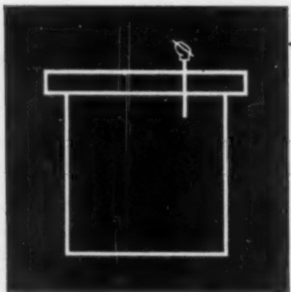

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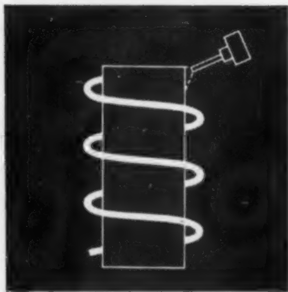

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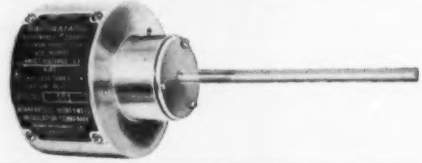



ANOTHER RYERSON PLUS: Steel Specialists

Metal Progress

Vol. 76, No. 2 August 1959

Critical Points

By the EDITORS

Should We Go to the Metric System?

The answer to this question has intrigued deep thinking Americans from both industrial and scientific fields since the metric system was adopted by the French in 1801. Now 158 years later, Admiral Lewis L. Strauss, our former Acting Secretary of Commerce, suggests something be done about it. In a talk given before the American Physical Society in Washington, D. C., last May, he proposes that the director of the National Bureau of Standards organize a group to assemble all available documents and suggest future plans for conversion to the metric system.

In many ways, he has a lot of logic on his side. When you think about it, our English system of measurement is decidedly cumbersome. Furthermore, it is based on such archaic standards as the length of a grain of barley (three barleycorns make an inch, according to England's King Edward II) and the average weight of a grain of wheat (7000 of them weigh a pound). Not only that, but the systems used in the United States and in England were, until very recently, slightly different. Last winter, laboratories in countries using the English system established the inch as equal to 25.4 mm.; until then, the American inch was 29/10,000,000 longer than the British inch. While this may not sound like much, it was often necessary to convert between English and American inches for precise measurements. Further, there is no interrelation between the English length and weight measuring systems as there is in the metric system.

Arguments used by Admiral Strauss on behalf of the metric system are quite impressive. However, most of them are old stuff to scientists who have been using the metric system in their laboratories for many years.

Most of you know that the metric system is easier to use. Based on decimals as it is, multiplication is a simple matter of adding zeroes. Conversion between scales is made very easy by interrelations. For example, at standard tem-

perature and pressure a cubic centimeter of water weighs one gram (weight) and is equal to one milliliter (volume).

The Admiral elaborates on the system's convenience with the following remarks, "Most of our daily measurement would become more accurate. Bookkeeping and computational requirements would be reduced. Our international trade, our buying, and our selling, and many of our international aid and security programs would be facilitated".

According to him, the changeover in many instances will be simple because it will merely involve a matter of usage. For example, distances can be measured in kilometers instead of miles. You can be overweight in kilograms rather than pounds; after all, the calories you count are already in metric units. Your car can burn liters of gas just as fast as gallons of gas.

Incidentally, in some areas, other than scientific, the metric system is already used. The pharmaceutical industry has gone over to it. Hospitals also weigh new babies in grams; this, of course, requires proud parents to multiply by 0.002205 so that they can brag about the weight in pounds. Such is the illogic of tradition. Certainly, a figure like 2040 g. sounds more impressive than 4½ lb.

Admiral Strauss goes on to say that there are two compelling economic reasons for making the change. For one thing, our country, through the Point IV program, is helping other nations to take advantage of modern technology and raise living standards. In this work, our experts are having trouble in dealing with foreign systems. Other nations have difficulty with our instruments because they are labeled in the archaic English system. Also, our foreign trade is hurt because we do not produce and label our products in the metric system. According to the A.A.A.S. Committee on metric usage, "We have discovered genuine concern (bordering on alarm) by experts in foreign trade over the failure of our manufacturers and packaging concerns to explain contents, dimensions and similar items in terms of metric units in catalogs, specifications and on labels".

Most of you will admit that the Admiral knows what he is talking about. We all agree that the metric system is much simpler and easier to use than the English system. Furthermore, changeover in some areas of the economy would not be difficult. It's the *other* areas that would give the trouble. Industrially speaking, the changeover to the metric system would be incredibly hard. Take the fastener industry, for instance. Every screw, nut, bolt, rivet, nail and other type of fastener is measured in the English system. Furthermore, these items – millions are made daily – often fit into holes which must be measured in the English system to correspond to the fastener's diameter.

If this doesn't frighten you, take a look at the machine tool field. Large manufactured items, such as automobiles, tractors, refrigerators, and the like, generally have hundreds of different parts. These parts have English dimensions and are produced by machine tools which are, in turn, built according to English dimensions. One machine may make parts for several different assemblies. Conversely, one assembly (a Pontiac sedan, for example) might require parts from many different machine tools.

Again, consider controllers. Most thermometers are Fahrenheit and pressure gages are lb. per sq.in. To change the system, not only gages but charts for recording instruments would have to be changed. Think of the confusion!

In passing, our industrial system intermeshes to such an extent that changeover to the metric system could not be done piecemeal. Concerted action by all segments of industry would be essential. We can't begin to calculate what this would cost in time and money.

Yet, the Admiral's ideas are not to be taken lightly. Universal adoption of the metric system would certainly be a boon to world trade. It would also simplify life considerably for those scientists and engineers who must now use both systems. On the other hand, it would cost industry a small fortune to make the drastic changeover that would be needed. Thus, they question whether it would be worth the effort.

Since we don't know the answer either, we are asking *you* the question posed in the headline for this column on the preceding page. More properly, this question should probably be written: "Would the convenience of the metric system compensate for the cost and trouble of adapting to its exclusive use". Since this is a matter which probably concerns most of you in some degree, you are likely to have an opinion. We would like to hear from you. A simple "Yes" or "No" will be enough, but a discussion of the problems or methods for changeover would be much more helpful. If there is enough interest, we will report the consensus of your opinions in our International Issue next January.

Fig. 1 – Pronounced Thermal Fatigue Cracks in Carburizing Tray

The Mechanism of Thermal Fatigue

*By H. S. AVERY**

Metal parts exposed to fluctuating temperatures for long periods eventually deteriorate. Experimental work and theoretical analysis indicate the cause to be plastic flow induced by expansion and contraction during heating and cooling. The effect can be minimized by proper design, selection of alloys that combine high hot strength with low thermal expansion coefficients, and by favorable operating conditions. (Q7j)

THERMAL FATIGUE, sometimes called "fire cracking", is considered by some as the principal mechanism by which heat resistant alloys deteriorate in use. It is the obvious failure mechanism of carburizing fixtures (see Fig. 1), and has become an important problem in the utilization of alloys in steam power plants, heat treating furnaces, nuclear power plants, and petroleum refining. The basic mechanism of thermal fatigue seldom operates entirely alone, but is often modified by oxidation, carburization, changes in internal structures and other variables. Defects, sharp angles, or changes in metal thickness may play a part, and service conditions obviously have important effects.

While the mechanics of thermal fatigue have been recognized and understood by a few scientific workers, they have usually been dealt with as difficult mathematical problems. A clear explanation together with experimental evidence has been difficult to find. Our purpose is to explain this puzzle in a simple way. We will show how the mechanism works and point out measures that can increase life expectancy.

Thermal shock is a related condition often confused with thermal fatigue. They are not the same, though both involve thermal stresses that can lead to failure. Thermal shock can be defined as a sudden change in temperature. Ductile metals respond to thermal shock by deformation but seldom break, while brittle material is likely to fracture. This would be "thermal shock failure". However, if thermal shocks (which are a part of service conditions) are applied repeatedly and there is some structural damage, the correct term is "thermal fatigue".

Thermal shocks can cause thermal fatigue, but shocks are not necessary. Repetition of slow heating and cooling, if it causes thermal stresses, can also produce the same kind of failure. It is helpful to think of thermal shocks, thermal gradients and temperature fluctuations as factors that produce dangerous stresses. These induce progressive deterioration or fatigue damage that leads finally to thermal fatigue failure.

*Research Metallurgist, Research Center, American Brake Shoe Co., Mahwah, N.J.

Some fundamentals explain these effects. First is the fact that solids expand and contract as they are heated and cooled. The common heat resistant alloys used for furnaces increase in length from about 1.10 to 1.60% when heated from room temperature to 1600° F. Thus, the highest expansion is about 45% greater than the lowest. Though significant, this alone does not explain many of the service observations.

Yield strength is also important. When a metal is compressed or stretched, it will deform like a spring until loaded beyond the elastic limit. Then plastic flow results, and changes the original dimensions. At high temperatures, metals become plastic so readily that measurement of an elastic limit may be difficult. Even if one is determined, it may be only an elusive figure that is tied to one rate of loading. Furthermore, as time passes, slow plastic flow or creep occurs even though tensile tests indicate that the same load causes only elastic behavior.

Phase changes enter the picture, too. A heat resistant alloy usually consists chiefly of a single phase, austenite, when it is cast. (With high carbon there may also be small crystals of chromium carbide scattered through the austenite matrix.) This austenite is sluggish; carbon held in solid solution is reluctant to form free carbides below 800° F. even though the austenite is supersaturated. However, at higher temperatures (especially between 1000 and 1900° F.) this sluggishness is reduced and carbides are rejected from solid solution. This precipitation is important in strengthening heat resistant alloys.

With cycling temperature, exposure during the top portion of the cycle may induce such carbide precipitation, thereby raising the yield strength. Thus hot strength can increase during a service interval. Weakening can also occur if the maximum temperature is high enough to redissolve precipitated carbides.

Expansion and Plastic Flow

The forces of thermal expansion are tremendous. They will push against the restraint of a rigid body, but if it does not yield, their efforts will turn inward and the expanding zone will become shorter and thicker.

Expansion and flow are expected upon heating, but at the same time, yield strength decreases as temperature rises. At a certain temperature, depending on alloy and design, the yield strength is exceeded by the stresses of hindered expansion, and the resulting plastic flow has a profound effect. It can be described by following the behavior of a short bar, originally free from stresses. Normal expansion upon heating would make it longer. However, if the end is held in position so that lengthwise expansion cannot occur, something else must happen. The bar expands in thickness and lateral plastic flow or upsetting develops. There is also a side effect. Since only those stresses above the elastic limit are converted to flow, the remainder are present as internal compressive stresses.

Cooling unloads or removes internal stresses. After the stress has fallen to zero, further cooling will shorten the bar if it is free to contract. If it is not, tensile stress will build up, and when yielding occurs, the bar will stretch, contracting in thickness at the same time. The end result, when cold, will be a bar of the original length, but held so only because of internal tensile stresses. Note that, first, flow in compression, and then flow in tension can happen. Each temperature cycle will produce these. Eventually such back and forth working of the metal will produce structural damage, and fatigue failure sets in. Uneven heating can also cause these sequences of stress and flow. Surface heating or cooling is the rule, with the interior lagging behind in temperature.

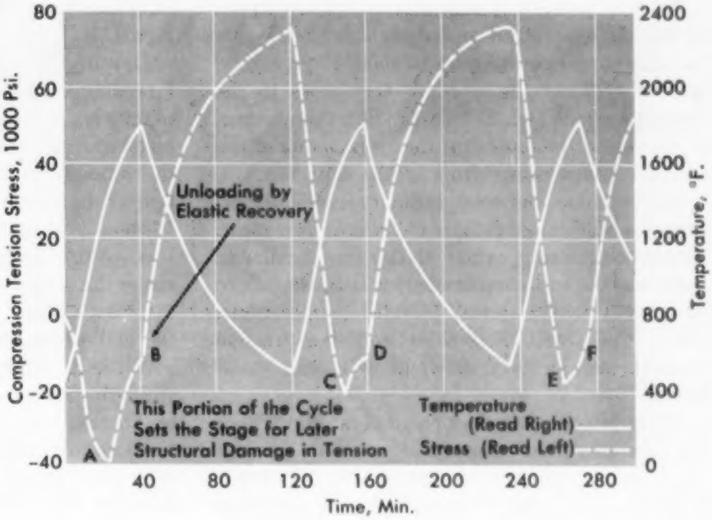
Experimental Verification

To demonstrate the validity of the stress and flow patterns described above, special apparatus was built. With this device, a bar is positioned in a very heavy frame, and screwed into strong grips that place another "weigh bar" in series with it. The setup is clamped rigidly at each end. The weigh bar carries strain gages that activate a recorder to measure stress. A gage length of reduced diameter is provided in the specimen bar; this zone is heated. Now, refer to Fig. 2 and follow the sequence of events as the specimen is heated and cooled.

The specimen is clamped into position at 500° F. When the power is increased in the small furnace around the gage length zone, the gage length* heats and the bar tries to lengthen.

*Incidentally, the entire bar column (test bar, connection grip and weigh bar) is about 35 in. long, but only about 5 in. of this is heated. The expansion of this part compresses the rest of the bar, but the total length remains constant. In the weigh portion this compression is all elastic, so that strain gages can measure the stress that develops. The heated gage length has a thermocouple attached. This connects to a recorder and to the furnace control, which in this instance was set to shut off at 1800° F. and to turn on at 500° F.

Fig. 2 — Temperature and Stress Curves for Typical Experiment. Points A to B, C to D, and E to F represent plastic flow in compression.



But being rigidly clamped, the force compresses the bar elastically. The specimen is now heating, and reaches 1800° F. after about 40 min.

At the same time, stresses can be followed on the dashed line. Beginning at zero stress and zero time, compression stress builds. For 20 min. this stress is elastic and increases steadily to nearly 40,000 psi. at about 1300° F.

The yield strength of metals decreases with temperature rise. When the build-up of stress reaches this yield strength, plastic flow sets in and prevents any further internal stress. The decrease in yield strength shows on the stress curve as a steady fall of stress from 20 to 40 min., as the bar heats from about 1300° to 1800° F. Plastic flow appears as a slight thickening or barrelling of the gage length.

Contraction Induces Stresses

At 1800° F., power is shut off. The hot zone of the bar contracts; this being a movement opposite to elastic compression, the internal stress is reduced. The stress returns to zero at about 1640° F. Below this, contraction is hindered, and the shrinking gage length stretches the remainder of the bar column. Stress in tension steadily develops. At first it is elastic, but, when the yield strength is reached, flow again occurs, this time to produce extension of the gage zone. By the end of the cooling cycle, the tensile stress has risen to about 75,000 psi. (The yield strength is normally below 40,000 psi.)

At 500° F. the furnace starts heating again and the bar tries to lengthen. This operates to relieve elastic stresses. Slightly less than 20 min. after heating resumes, the bar has reached about 1300° F., and the tensile stress has fallen to zero. (Note: On this second cycle, zero stress occurs at 1300° F., whereas it was at 500° F. when the test started. This profound change is the result of the plastic flow that occurred.)

As heating continues, the earlier sequence is repeated: elastic compressive stress builds up, the yield stress is exceeded, and flow reduces stress until the maximum temperature is reached. In this cycle, the maximum compressive stress is lower (about 22,000 psi.), but the stress at 1800° F. is about the same, and corresponds to a yield strength at this temperature. There is less plastic flow because the zero stress temperature is higher than for the first cycle. Subsequent cycles are very similar to the second.

Concerning this particular specimen, comparatively large amounts of plastic flow occurred, causing failure after three cycles. By changing the test conditions (for example, by thickening the gage diameter to reduce unit stresses), the flow on each cycle can be reduced and the number of cycles to failure increased.

Discussion of Tests

Looking carefully at this sequence of events, it is evident that plastic flow is chiefly responsible for thermal fatigue. After the first stabilizing cycle, compressive flow occurs over a fairly narrow temperature range. If test conditions were changed so the maximum temperature was about 1550° F. (instead of 1800° F.), compressive flow would be substantially avoided and long life despite cycling could be predicted.

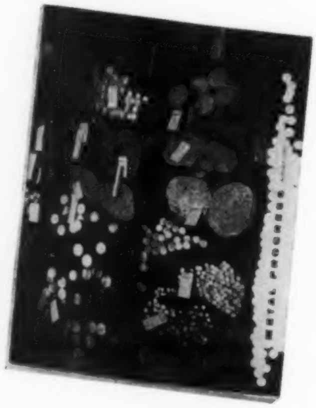
Another aspect concerns service life of furnace parts. If experience and design are such that furnace parts operating up to 1550° F. give good service life, but are working very close to the temperature at which plastic flow can occur, a moderate increase in the top temperature might cause a sharp drop in life expectancy.

The relation between ordinary metallurgical fatigue and thermal fatigue is perhaps now clear. Alternate stressing, when plastic flow occurs in both tension and compression, will cause failure at normal temperatures. Cyclic temperatures, when the resultant tensile and compressive stresses each produce flow, likewise can cause failure.

Other factors also affect thermal fatigue. There are metallurgical complications that require much additional study. Design is important. Heat transfer, which controls the temperature gradient (and thus the expansion differentials that may cause flow and distortion), is a major factor.

Despite these and other complications, several facts stand out. Thermal expansion is basic and, other things being equal, a low expansion coefficient helps to increase life expectancy. Both the amount of restraint and the range of the temperature cycle affect life expectancy greatly. Without restraint, expansion is relatively harmless. With restraint, the greater the heating range the sooner failure can be expected. There can be a critical top temperature (or amount of thermal expansion) beyond which flow occurs and life is sharply reduced. A higher yield strength may raise this temperature. The speed of heating and cooling, because it establishes temperature differentials, greatly affects the amount of stress and flow produced, and this influences life. This factor is frequently under control of the alloy user.

On the Cover | How to Tell One Bar From Another



Recently, the editor toured the plant of Joseph T. Ryerson & Son, Inc., in Chicago and this month's colorful cover shows one of the many scenes which he viewed. It illustrates a rack of bars which have been systematically color-coded. The Ryerson people made several color transparencies for *Metal Progress* to consider as a front cover subject and this one was selected as the most colorful. We think you will agree that it makes the grade in grand style.

The revised and improved color code developed in 1956 by Ryerson can be expanded to include any new steels, the company said. Each color has a definite meaning in the system. For example, single colors identify standard carbon and carbon-manganese steels. Carbon content is defined by four colors: green (under 0.30%), blue (0.30 to under 0.40%), yellow (0.40 to under 0.50%) and pink (0.50% carbon and above). Thus, 1018 and 1020 are green on one end while 1035 is blue. If the carbon color is centered as a dot on the end, the bar has been heat treated. However, centered dots can be of other colors. When they are, they indicate characteristics other than analysis, carbon range, or heat treated condition.

Other colors also designate related groups of steels. For instance, black is used for the standard 4100 series, white for the 4300 and 4600 series, orange for the 8600 and 8700 series, and gold for the 6100 and 9300 series. Alloy steels generally have two colors, one for the group, the other for the carbon content. For example, 4140 will be black and yellow, and 8620 will be orange and green. Purple says the steel is a leaded free machining type. Red, in any form, indicates a special ground finish. Toolsteels are painted full length; other bars are painted on one end only.

Ryerson regards this as a most useful system and is using it throughout all of its plants. The company says the system also helps its customers to exercise better control over material and to avoid mixed steels.

Reduction of Warpage

. . . by Die Quenching of Steel

*By T. R. BRADLEY**

The trend to higher strengths has resulted in steel parts which are too hard to machine or bend after tempering. Thus, dies which hold the part in shape during quenching are being used more and more. (J26n; ST, 9-74)

It is true that the heat treat procedure for one tensile level is much the same as that for another tensile level – except for the final tempering or aging temperature. However, this exception becomes the main factor when we try to control distortion. When the tempering temperature has been high enough to produce a low tensile strength (150,000 psi., for example), the metal is still soft enough to be machined or straightened. As the tempering temperature is lowered, the tensile strength increases, and these operations become more difficult.

Furthermore, undesirable residual stresses are produced, and in some applications these cannot be tolerated. The use of heat to aid straightening is also limited; temperature must be lower than the tempering temperature, otherwise the part will soften. Since there is apparently no practical way to remove distortion once it occurs, some form of warpage control must be used.

Why Steel Warps

A steel part warps during heat treatment because all zones of the part are not at the same temperature at the same time during heating and cooling. Consequently, the various sections of the part are not contracting or expanding at the same rate. This is most pronounced during the cooling cycle, especially if rapid cooling (such as quenching into a liquid) is required. Not only does the thermal contraction cause warpage, but the transformation to martensite causes additional changes in dimension. The growth of semi-austenitic stainless steels during transformation results in severe distortion of the part.

Usually, heavy sections are corrected by final machining after heat treatment. However, if warping can be controlled appreciably, most machining operations can be done before hardening with resultant cost savings.

Light sections, normally not machined to any extent, may present a more difficult problem. These parts must maintain their exact contour through the hardening cycle, or be contoured during the tempering cycle.

How to Control Warpage

Warpage can be controlled by three basic methods:

1. Dimensional allowance can be made for the growth due to transformation, and all sections of the part maintained at the same temperature during the cooling cycle.

2. The part can be shaped to contour during the tempering cycle.

3. The part can be physically shaped and held while it cools from the hardening temperature.

Some success is obtained by the first method. To reduce distortion in a part, it is often necessary to increase the cross section of the thinner areas so that they approach the thickness of the heavier sections. This can be done by attaching "heat thieves" or "robbers" (additional pieces of steel) with suitable clamps or wedges. The cooling rate can also be lowered by raising the temperature of the quenching medium.

The second method requires a fixture, usually quite massive, to hold and straighten the part during tempering. However, a certain amount of warpage control during quenching is still

*Supervisor, Liaison Engineering Laboratory, Rohr Aircraft Corp., Chula Vista, Calif.

needed so that the part can be placed in this tempering fixture.

The third method relies on dies or fixtures to hold the part in contour during the last phase of the cooling cycle. In some instances, the die quenches the part, in others, both die and part are quenched.

When Die Quenching Is Feasible

Before resorting to die quenching, the heat treater must consider the quench rate required for hardening. As examples, steels 4130, Type 410 stainless, 4340, H-11, and 17-7 PH (listed in order of increasing air hardening characteristics) are some of the steels that can be die quenched. Steel 4130, normally considered to be an oil hardening grade, can be quenched by dies if the gage is small enough. Of course, the part must be transferred rapidly to the die. If these criteria cannot be met, a liquid quench is also needed.

Type 17-7 PH represents the other extreme; it can be cooled in a die very easily. Within practical limits, the cooling rate for 17-7 PH is not critical, providing the part is placed in the die before martensitic transformation has begun (about 200° F.).

Another consideration, as always, is cost. Usually the dies or fixtures are quite expensive. Unless a large number of parts are to be produced, their cost may not be justifiable. However, if this is the only way to control some parts, the expense becomes a necessary evil.

Two Typical Examples

Figure 1 shows a part, 0.031-in. gage, which is quenched and formed at the same time. The material is 4130 steel. A flat blank is heated to 1600° F. in a furnace, then rapidly transferred to a die which is located in a small hydraulic press. The die, which is water cooled, quenches the part. (Though water cooling is not essential, it is used because the die heats up after several parts have been formed.) The part is then tempered to 180,000 to 200,000 psi.

The dies for this part are quite expensive, since matched steel forms, locating pins, and internal cooling are needed. However, this was justified because a large number of parts were to be produced and two forming operations were saved. In comparison with other alternatives (such as tempering fixtures), the die quench method was the most economical. Of course, hand working after heat treatment, though possible, is never satisfactory.

Fig. 1 – Part Which Is Quenched and Formed at the Same Time. Made of 4130 steel, this part is heated to 1600° F. and quenched with a water cooled die. Though dies for this part were expensive, their use was justified because many parts were made and two forming operations were eliminated

Another long, narrow part is cooled on a fixture which is used for various 17-7 PH parts of similar shape. The fixture accommodates 12 parts at a time. After removal from the transformation furnace (1400° F.), parts are placed on the bottom pad. The top flexible pad is lowered and secured to hold these parts under pressure until they can be handled with bare hands. After refrigeration they are precipitation hardened to 180,000 to 200,000 psi.

These dies are simple. The bottom die matches the contour of the formed part, while the top die merely serves as a pressure pad for holding the part against the bottom die. Both dies are made in sections which are held together with springs. Tension holds the part in place, yet allows enough flexibility for the two dies to mate. Since this method of forming is cheap, it is used wherever possible. Furthermore, hand working is completely eliminated.

Die quenching is usually chosen for warpage control wherever it is economical or where straightening after heat treatment is not permitted. Also, no other way for controlling distortion may be possible if the part is complex and high tensile strength or low tempering temperature is required.

There are many designs where die quenching may be applicable. The process is already being investigated as a method of controlling warpage during brazing and heat treatment of steel sandwich honeycomb structures. Further work with ultra-high-strength materials should develop some new and novel refinements of die quenching techniques.

Reduction of Warpage

. . . by the Thermomechanical Method

By H. N. HILL,
R. S. BARKER
and L. A. WILLEY*

Cooling to subzero temperatures and reheating rapidly can introduce residual stresses opposite to those produced by conventional quenching. This is the basis of a new method of stress-relieving aluminum parts of irregular shape. (J29a, J26q; Al, 9-74)

A NEW WAY TO RELIEVE the residual stresses in quenched aluminum parts has been devised: Quenched parts are cooled to −320° F. in liquid nitrogen and then heated rapidly in a blast of steam. Since this technique is essentially the reverse of quenching (the parts are rapidly heated, rather than cooled, through an extensive temperature range), stresses induced by previous quenching are reversed and largely canceled out. Already effective with some forgings, this treatment is expected to be useful for stress-relieving irregularly shaped parts that cannot be handled by other methods. This will be a boon to aluminum fabricators since stress-relieving may present difficulties.

Problems in Stress-Relieving

To make this clear, let us consider conventional practices. Many commercial aluminum alloys attain their strength through heat treatment. While the specific treatment depends on the alloy, the part is usually quenched in water from about 900° F. Stresses occur because the surface cools faster than the center, and temperature gradients spread throughout the part. When the bath temperature is finally reached, these gradients vanish, but in disappearing they set up a system of residual stresses. Usually, the surface is in compression and the center is in tension. Stress magnitudes vary with alloy and severity of quench. Solution treatment is generally followed by precipitation hardening or aging at 250 to 450° F. This treatment further enhances the strength but has no significant effect on the residual stresses.

For many applications, the stresses resulting from heat treatment are harmless. (In fact, where fatigue or stress-corrosion is involved, they can be beneficial.) However, when a heat treated part is machined, removal of metal disturbs the original stress balance and a new balanced system must be set up. When this happens, the part usually warps. Since this can be a serious problem, material with a low level of residual stress must be supplied if it is to be machined later.

*Alcoa Research Laboratories, Aluminum Co. of America, New Kensington, Pa.

Residual stresses can be relieved by heating or by mechanical deformation. However, heating is not practical for heat treated alloys because temperatures high enough to relieve stresses lower the strength. As described in *Metal Progress*, March 1959, p. 112, deformation by stretching is regularly applied to products of uniform cross section such as sheets, plates and extruded shapes. Parts not suited to stretching, such as hand forgings and some die forgings, can be compressed. Stretching and compressing have some minor effects on mechanical properties. In irregularly shaped parts where these methods are impractical, there was need for a method of relieving residual quenching stresses, preferably one that would have no detrimental effect on mechanical properties.

Table I – Effect of Reheating Method

Cooled to	Method of Reheating	Maximum Temperature Difference*	Reduction in Residual Stress Range†
–100° F.	Boiling water	110° F.	19%
–320	Boiling water	110	19
–100	High-velocity steam	219	48
–320	High-velocity steam	371	82

*Between surface and midplane.

†Related to material not given the thermomechanical treatment.

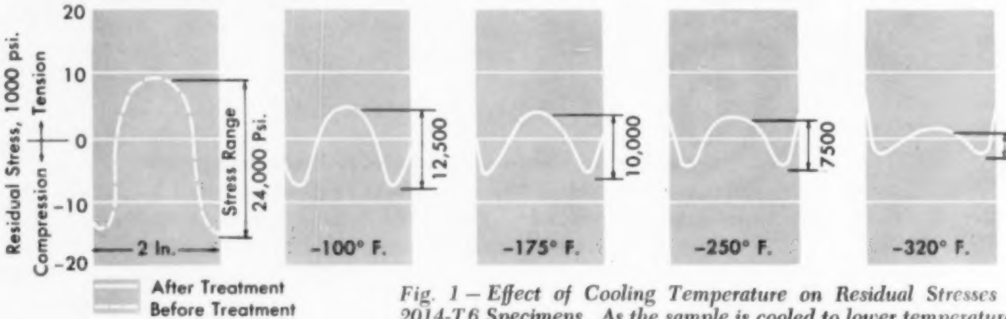


Fig. 1 – Effect of Cooling Temperature on Residual Stresses of 2014-T6 Specimens. As the sample is cooled to lower temperatures, the steam blast which follows causes a more drastic reheating. The imposed stresses reverse those produced by previous quenching; the resultant stress level is thus very low. All samples are 2 in. thick

Principle of "Uphill Quenching"

It was reasoned that, since residual quenching stresses result from thermal gradients introduced when the part is being cooled, it should be possible to produce opposing residual stresses by heating a cold piece rapidly. In other words, an "uphill quench" was needed. Residual stresses thus developed should counteract and cancel the quenching stresses. To be effective, such a "quench" would have to produce temperature gradients large enough to cause local plastic deformations. Furthermore, temperatures should not be high enough to affect properties. These requirements suggest cooling to a subzero temperature and reheating rapidly.

The method developed involves an "uphill quench" of such severity and applied under such conditions as to result in considerable reduction in residual stresses, with no effect on mechanical properties. It has been labeled "thermomechanical" to connote that, while the treatment is thermal, the relief of residual stresses comes through mechanical plastic deformation.

The procedure* is as follows:

1. After quenching, and before appreciable precipitation hardening has occurred, cool the part to a very low temperature.

2. Remove part from the cooling medium and immediately blast all surfaces with steam at high velocity.

3. Age the part as prescribed for the specific alloy.

This treatment has lowered the level of residual stress in aluminum parts more than 80% without changing properties significantly.

Experimental Work

Without going into detail, it might be well to describe some of the research. Samples of 2014 and 7075 aluminum alloy plate were quenched from the solution heat treatment temperature, cooled to subzero temperatures and rapidly reheated. Best results occurred when

*Aluminum Co. of America patent pending.

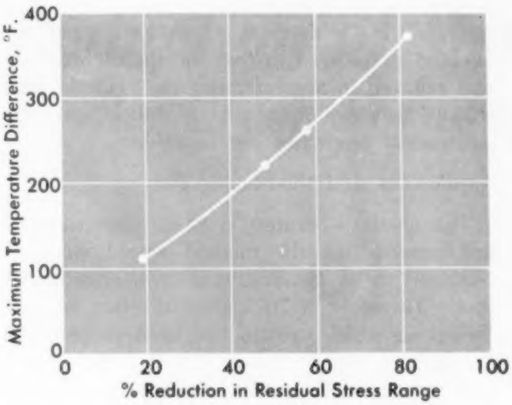


Fig. 2 – Relation Between Maximum Temperature Difference and Reduction in Residual Stress. Temperature difference is between surface and midplane, and reduction in stress is related to material without the thermomechanical treatment

the specimens were blasted with steam directly from the −320° F. of liquid nitrogen. Residual stresses were determined by measuring the changes in length and curvature which occurred when the alloy plate samples were sectioned.

Description of the state of residual stress involves both magnitude and distribution. It cannot be expressed completely by a single number. To simplify comparisons, however, it is desirable to have such a numerical expression. For this purpose, the range of residual stress is defined as that between the stress value at mid-thickness and the maximum stress of opposite sign at or near the surface. This range of stress is illustrated in Fig. 1.

Cooling Temperature

Cooling to −100° F. followed by rapid reheating with steam resulted in a reduction in stress level of about 50%. Greater reductions were obtained with lower temperatures. The maximum temperature difference between surface and center increases as the cooling temperature is lowered. The close relationship between the maximum temperature difference measured between surface and center and the reduction in residual stress level is shown in Fig. 2.

Method of Reheating

Boiling water immersions or hot water jets were not adequate for "uphill quenching". Only the steam blast reduced residual stress to the desired degree. Two features of the steam blast help to attain the required high heating rate – the heat of condensation of the steam, and the

Fig. 3 – Equipment for Stress-Relieving a Die Forging. Tanks in the foreground are for the coolants; the steam fixture above does the reheating

blast which removes the condensate from the surface of the part being treated.

As shown in Table I, the effectiveness of the steam blast was influenced by the temperature to which the part was cooled. The reduction in residual stress was greater when the 2014 samples were cooled to −320° F. than when cooled to −100° F. When reheated by immersion in boiling water, however, the maximum temperature difference between surface and center and the reduction in residual stress range were the same whether the sample was cooled to −320 or to −100° F. In either instance, the reduction in stress range was only about 20%.

Yield Strength – Time After Quenching

For the "uphill quench" to be effective, the thermal gradient must be great enough to produce local plastic deformation in the part. Thus, for a given thermal gradient, the effectiveness will depend on the yield strength of the material. For this reason, the thermomechanical treatment must be applied before the yield strength has been raised by aging. The treatment is ineffective if applied to a parts in the T 6 temper. Tests also showed that residual stresses could be induced in annealed material (in other words, material without residual stresses) by "uphill quenching".

It is evident that the thermomechanical treatment cannot be applied indiscriminately. It is intended only for those parts having appreciable residual stresses introduced by quenching.

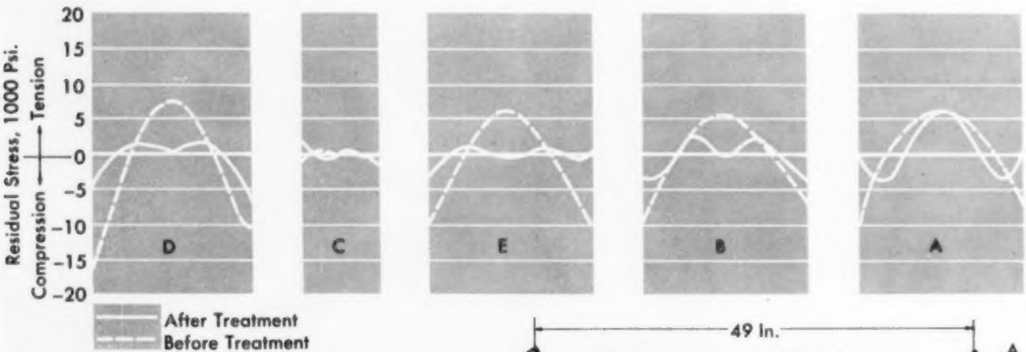
Recycling was ineffective; the same degree of stress-relief could be obtained with one "uphill quench" as with five. Specimen thickness affected stress-relief in that the thicker material was relieved to a greater degree. Tensile tests showed that "uphill quenching" did not alter the mechanical properties significantly.

Application of Method to Die Forging

Though the laboratory work on plate samples had proved that the method would work, it remained to be demonstrated on a commercial part. Therefore, a 7075 alloy die forging was chosen on which stresses had been successfully reduced by compression. Figure 3 shows the forging and the equipment built for "uphill quenching". One of the tanks in the foreground contained a dry ice trichlorethylene mixture for precooling, and the other held liquid nitrogen (−320° F.) for final cooling. For reheating, steam was admitted at the top of the heating fixture into a plenum chamber partially surrounding the part. It reached the surface of the forging by expanding through rows of holes along the top and sides of the inner wall of the chamber. Excess steam and condensate escaped through holes on the bottom cover.

The effect of the treatment is shown in Fig. 4. Although relief varies at different sections, stresses were reduced considerably in all regions where they were high. When these results were compared to those obtained on an identical die forging which had been relieved by compression, stresses were found to be at the same low level.

On the basis of this success, further work is being done to develop the treatment as a commercial procedure.



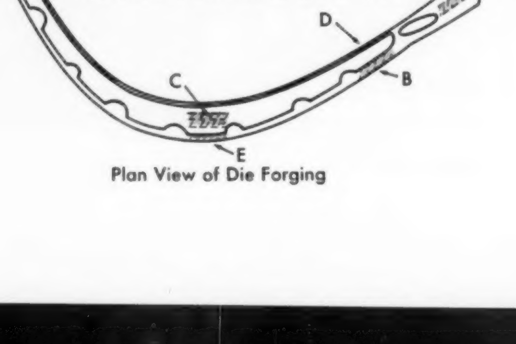


Fig. 4 – Response to Thermomechanical Treatment of 7075 Die Forging. The treatment has reduced residual stresses appreciably. Section C is 7/32 in. thick; the rest are 2 5/16 in. thick

Reduction of Warpage

. . . by Creep Forming and Die Quenching of Nonferrous Alloys

*By JOSEPH SOJA**

Jet planes are built with large and complex parts made from high-strength materials. Often, these parts are difficult to form by conventional means and special forming methods must be developed. Three new techniques are discussed. (G-general, T24a; Al-b, Ti-b, 9-74)

WITH THE GREAT STRESSES and temperatures which are generated in today's fast flying aircraft, many problems must be met and solved. For one thing, the modern jet plane cannot face this tough environment unless high-strength materials are used for the large, complex parts and sheet metal components. Because such items cannot readily be forced into "fit" for assembly on the airframe, they must be machined or formed (or both) to close tolerances.

Many assembly problems occur when the first (or prototype) airplanes are "hand made" with existing or slightly modified equipment. During this phase, deficiencies in equipment, manufacturing techniques, and production scheduling become apparent. For example, work on prototypes at North American Aviation revealed that three types of parts could not be economically formed to the required contours in the amounts needed for production. These were:

1. Large, integrally stiffened, contoured wing panels.
2. Wing skins with thin, high ribs.
3. Titanium sheet metal parts.

In all three categories, only the use of heat, fixtures, and forming dies eliminated the costly and time-consuming methods needed for close contour. We found that the wing panels could be formed hot after prestressing (creep forming), the wing skins were easily shaped by quenching in dies made from metallic shot, and titanium sheet could be sized while hot. To illustrate this, we will consider each problem and its solution under separate headings.

*Materials and Processing Engineering, North American Aviation, Inc., Inglewood, Calif.

Contoured Wing Panels

At the beginning, brake forming was the only method considered practical for shaping wing panels. (The cost of press equipment and dies for die quenching would have been prohibitive, while the thickness of the parts made shot forming impossible.) Therefore, the first panels were contoured on a large hydraulic press brake. Almost immediately, we ran into trouble for several reasons. The part cooled rapidly and needed many reheats, and the large size made handling and checking very awkward. Furthermore, the irregular shape required special forming setups, and areas adjacent to the heavy sections were extremely difficult to contour. More than 24 hr. was needed to form a single part.

This experience indicated that a new concept in forming was required. After much work, we evolved a creep forming method which we call "prestress hot forming"†.

Briefly, the part is overcontoured in a jig (as in Fig. 1) at room temperature. It is then heated to about the artificial aging temperature of the alloy. Although stresses introduced by jigging are below the yield strength of the material at room temperature, they are above the yield strength at the higher temperature. Thus, permanent deformation occurs during heating and is retained when the part cools. Since forming temperatures are near the artificial aging temperature, and the time at temperature is relatively short, 7075-T 6 hot formed by this process needs no further heat treatment.

In developing this process, we found that

†Patent No. 2,724,669.

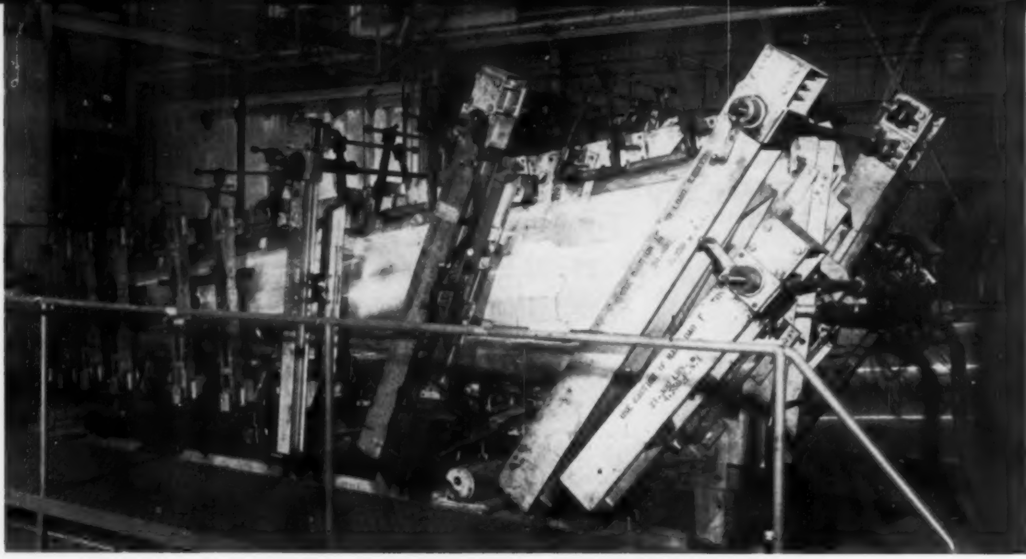


Fig. 1 – Wing Panel Being Overcontoured for Creep Forming. After clamping at three to five times the curvature expected in the completed panel, the part is heated to the aging temperature for the required time for forming. The permanent deformation which occurs is retained when the part cools

satisfactory contour could be attained by forming at 350° F. for 45 min. With this cycle, the panel springs back to only one third of the original overcontour when the clamps are released.

Due to the large mass of the fixtures and the radical changes in section thickness, it was difficult to maintain a uniform time at temperature within the parts. Yield strength varies considerably with short times at temperature; consequently, the 350° F. cycle requires extremely accurate and careful control at all times. Laboratory tests, conducted to establish a less critical cycle, indicated that optimum mechanical properties could be obtained by heating to 275° F. However, the holding time increased to about 90 min., and overcontouring had to be increased to five times the desired contour to compensate for greater springback at the lower temperature.

In addition to the complete cycle of 2.8 hr. (for two parts), it was occasionally necessary to "touch up" the wing panels on the press brake. This "touch up" required about 1 hr. for each part, and was usually completed before the next batch was removed from the oven. Production records for several thousand wing panels reveal that only 0.7% scrap can be attributed to the new process.

From the preceding discussion and Table I, the advantages of prestress hot forming over brake forming of wing panels can be listed:

1. No additional treatment is required after forming.
2. Contour is more accurate and uniform; this aids installation.
3. Initial equipment cost is lower for high rate of production.
4. Operating costs are lower.

Wing Skins With Thin Ribs

Thin wing skins could be formed by either prestress hot forming or form die quenching. Though the former method was the most desirable, it was difficult to maintain accurate contour on thin sections. Die quenching in form dies was considered too critical an operation because close contours were required in machining the part and matching the dies. Experience on similar parts indicated that a gap not over 0.004 in. could be tolerated between the part and the die to provide satisfactory properties. It would also be difficult to fit thin ribs into the die cavity.

One forming method remained – die quench-

Table I – Prestress Hot Forming Compared With Brake Forming

	Prestress Hot Form	Brake Form
Total man-hours per panel	5.8	85
Total forming cycle	2.8 hr. for two panels	28.6 hr. per panel
Equipment required for assumed full production of 85 panels per week	One oven (2 men each), one fixture, one brake (3 men, 1 hr. per part)	20 brakes (3 men each), 10 heating ovens (2 men each)

Table II – Mechanical Properties of 6061-T 6 Plate

	Yield Strength, Psi.		Ultimate Strength, Psi.		Elongation	
	Long.	Trans.	Long.	Trans.	Long.	Trans.
As-received plate (0.875)*	43,400	44,400	46,100	48,400	11.1%	7.2%
Reheat treated plate*	40,900	42,700	45,200	47,500	12.2	7.8
Formed part†	41,400	41,400	45,300	46,100	10.4	10.4
Required	35,000		42,000		10%	

*Control test plates
†Machined, form die quenched in metallic shot, and aged.

ing in metallic shot. In this, a contoured die, or punch, forces the part into a cavity filled with round metallic shot (usually iron or steel). As the pressure is increased, the shot conforms to the shape of the part and finally forces it against the contoured die. The shot also cools the part rapidly so that satisfactory properties can be attained in aluminum parts.

First, we made some preliminary tests to determine some of the processing variables. Ribbed plates (made of 7075, 6061 and 2024 aluminum) were machined, heated to their respective solution treating temperatures, and rapidly transferred to a 4500-ton hydraulic press. After applying pressure and allowing the parts to cool, they were remeasured, aged, and tensile specimens were pulled to fracture.

Several processing variables became apparent during these tests.

For example, when the transfer time from the furnace to the die did not exceed 19 sec., the mechanical properties were satisfactory. A dwell time which allowed the parts to cool below 200° F. was long enough. Press pressure was not critical. (However, it should be enough to insure intimate contact between the die, part and shot.) The machining tolerances of both the die and part had no appreciable effect on either the mechanical properties or contour. (This is a major benefit since the single die can be machined to standard tolerances.) Finally, the size and type of shot had no appreciable effect on either the mechanical properties or contours of the completed part.

One drawback was the erratic growth revealed by measurement of the parts. This was due to:

1. The applied pressure, which

Fig. 2 – This Wing Skin Has Been Formed by Die Quenching in Shot. The thin, high ribs make this part difficult to form by conventional methods

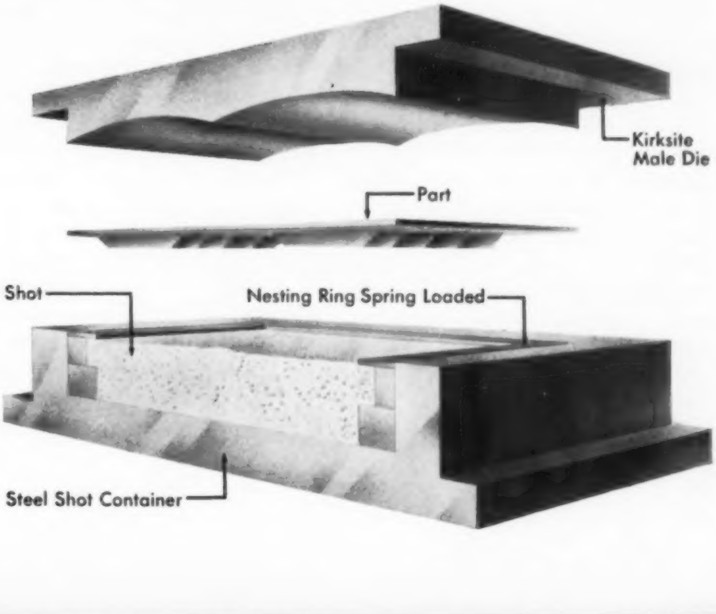


Fig. 3 – This Form Is Used for Shot Quenching. Only one accurately formed die is needed for this method

varied from 3000 to 10,000 psi. on the surface, resulted in a variation of the restraining pressure.

2. Orientation and rib thickness influenced the growth of the part. When the ribs were parallel to the contour, growth was slightly greater than when the ribs were transverse to the contour. The heavier the section, the greater the growth.

3. Growth of the parts was inversely proportional to the yield strength of the alloy at temperature. As a typical example of what can be done, consider the large part shown in Fig. 2. Containing numerous thin, high ribs which made it difficult to form by conventional methods, it was satisfactorily formed in metallic shot (Fig. 3). Table II shows that mechanical properties in the die quenched part were adequate even though transverse elongation was below specification limits in the control test plate before and after heat treatment.

Some of the attractive features of forming by die quenching in metallic shot are:

1. *Reduced tooling costs* – This process does not require matched tooling to the ±0.004 in. usually necessary for form-quench dies. Only the punch portion requires a smooth contour.

2. *Matching tolerances are eliminated* – Accurately matched dies are not required, and therefore the discrepancies always present between part and die are nonexistent.

3. *Part shapes are practically unlimited* – In shot die quenching, the thickness of the skin or height of the stiffeners has no apparent limit.

4. *Size limitation* – Size of part is limited by the equipment available for forming.

Contouring of Titanium Sheet

There are three stages to the history of the final contouring of titanium sheet. At the beginning, sheet metal parts were finished by hand working. This was time-consuming, costly, and resulted in much scrap. Next, sizing fixtures weighing up to 2000 lb. were used. The part was clamped in the fixture and placed in an oven for 1 to 6 hr. for finishing. Since this method was still quite costly, more research was done. This led to the third stage – the "hot sizing" method developed at North American Aviation. The hot sizing press is an overgrown "pants presser" with side rams. This press contains a hinged lid which applies a 300-ton vertical pressure on the part, and horizontal rams that apply a side pressure of 75 tons. The electrically heated platens in the lid and press bed can heat the dies to 1400° F.

The sequence of operations for sizing parts of titanium sheet is as follows:

1. Preform (drop hammer, stretch form, hydroform, and other methods).

2. Place the cold part on a hot die in the press and apply pressure.

3. Maintain pressure for 5 to 10 min., depending upon gage thickness and contour of part.

4. Remove the part from the press and cool uniformly without restraint.

This sequence, with minor variations, usually produces satisfactory parts.

Alloys of low and intermediate strength (A 55 and A 70 for example) can readily be sized between 900 and 1050° F. However, the high-strength alloys (A 110 At and annealed 6% Al, 4% V) require higher temperatures (1200 to 1400° F.) or longer holding times, or both. This results in surface contamination and die problems. In addition, if the age hardenable alloys (4 Al, 3 Mo, 1 V and 6 Al, 4 V) are hot sized for prolonged periods above the aging temperature (950° F.), mechanical properties are lowered.

A review of the problems associated with these high-strength alloys indicated that an intermediate sizing temperature was desirable. Why is this? Well, hot sizing and die quenching restrict the normal thermal expansion or contraction of the part. This redistributes the stresses, putting them in equilibrium so that little or no movement occurs when the pressure is released.

However, existing equipment could not exert sufficient pressure on larger parts to prevent thermal growth. Handling problems and die costs argued against die quenching. We decided, therefore, to investigate a new concept – "compression" forming. If a sheet metal part could be restrained to prevent thermal expansion, this might produce a straightening effect at intermediate temperatures (900 to 1000° F.).

We began the work on single-angle dies with restraining end plates. The dies were heated to about 900° F. between hot platens in a hydraulic press. Then, we put the part on the die, and applied enough pressure to hold it flat for 13 min. In these tests, the thermal expansion was restricted in varying degrees to determine the effect of restraint on the final contour.

Preliminary data have shown the idea to be practical. Compressive forces can be applied by restraining gutters or stops in hot sizing dies, or by exerting enough pressure. Surface contamination inherent in sizing at high temperatures will be eliminated, costly die steels will not be needed and a great variety of high-strength alloys can be sized.

Copper-Titanium Alloys Have High Strength

By M. J. SAARIVIRTA
*and HOWARD S. CANNON**

Strength exceeding 200,000 psi. can be reached with a new copper alloy containing 4.3% Ti. After solution treating, the alloy can be cold worked more than 90%. Subsequent aging develops the properties. (Q27a; 2-60, 2-64; Cu-b, *Ti*)

COPPER IS ONE of the world's oldest metals, titanium one of its newest. Both possess properties that make them extremely useful in today's industry. Now, these two elements have been combined – and a new high-strength alloy has emerged. With 4.3% Ti added, copper has a tensile strength above 200,000 psi. after cold working and precipitation hardening. Marketed under the trade name "Amtite", this alloy is now being used for electrical conductor plates and springs, and as a clamp die material in welding machines. Development is progressing rapidly, and many more applications are expected in the near future.

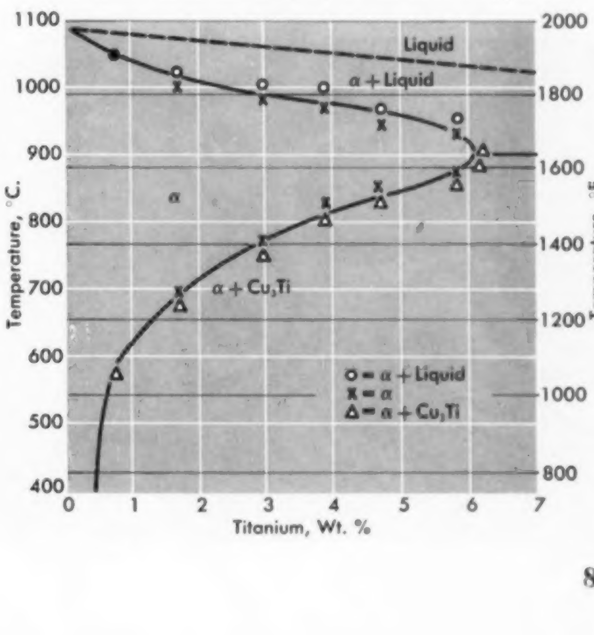
Strictly speaking, this alloy is not new, but the early investigators ran into several roadblocks. Titanium was first added to copper in the 1930's, but the alloys were never commercialized despite the high strength achieved. The cost of titanium along with the lack of facilities and techniques for handling reactive metals undoubtedly contributed to this neglect. In recent years, these barriers have been removed, and several new investigations have been carried out.

Though none of these report the ultra high strengths that can be obtained through optimum processing of the 4 to 6% Ti alloy, our work has produced strengths as high as 220,000 psi. They have been developed by capitalizing on the alloys' capacity to work harden extensively if prepared correctly.

We began by determining the copper-rich end of the Cu-Ti system. Raw materials used are listed in Table I. All physical properties were determined on alloys prepared from oxygen-free, high-conductivity copper and Cu-Ti master alloy. Only comparative hot workability tests were made with the other materials. We melted 4-lb. heats by induction in graphite crucibles under a helium or argon atmosphere. The alloys, held at about 2240° F., were bottom-poured into solid copper molds, 1.3 in. diameter by 15 in. long. Fourteen alloy compositions

* Mr. Saarivirta is senior physical metallurgist, Amco Research, Inc., Carteret, N.J. Mr. Cannon, formerly supervisor for Amco Research, is now with Continental Can Co.

Fig. 1 – Solid Solubility of Titanium in Copper



were made; they contained from 0.20 to 6.79% Ti. To determine the phase diagram, samples were solution annealed at 1650° F. for 20 hr., quenched to room temperature, and rapidly reheated to the desired temperature. After holding 2 hr. at temperature, they were quenched and examined microscopically for phases present. As the resulting diagram shows (Fig. 1), maximum solid solubility occurs at about 6% Ti. The microstructure of cast 4.3% Ti alloy is shown in Fig. 2. Alloys containing over 4% Ti develop a Widmanstaetten structure after heating at 1470° F., while, as shown in Fig. 3, a structure very reminiscent of pearlite is observed after heating at 1100° F. The latter structure forms only between about 930 and 1150° F. and grows outward from the grain boundaries. Since there was no visible precipitate below 840° F., the solubility of titanium in copper at low temperature was estimated by the alloy's response to heat treatment. The 0.34% Ti alloy shows no age hardening response while the 0.72% alloy does (see Fig. 4); consequently, the low-temperature solubility limit can be placed at about 0.5% Ti.

Table I – Raw Materials

	Cu	O_2	P	Ti
Oxygen-free, high-conductivity copper	99.99%	0.0001 %	<0.0002%	—
Fire-refined tough pitch copper	99.92	0.03-0.05	—	—
Electrolytic tough pitch copper	99.95	0.03-0.05	—	—
Phosphor deoxidized copper	99.9	—	0.015-0.03	—
Cu-Ti master alloy	72	—	—	28

Fig. 2 – Cast Structure of Copper (4.3 Ti.) Etched in $K_2Cr_2O_7$; 750×

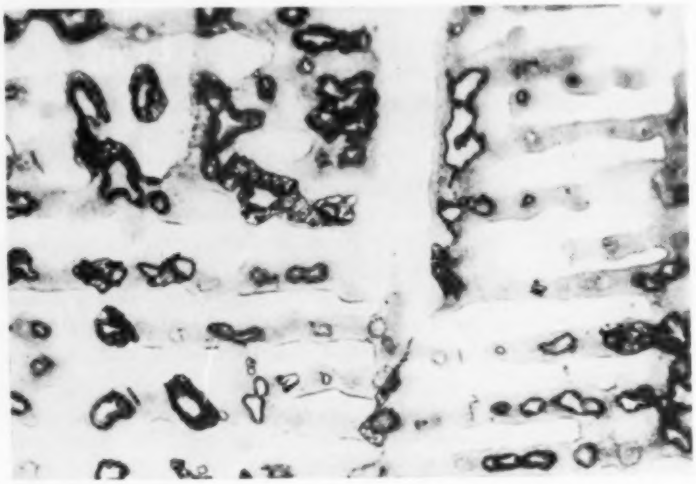


Fig. 3 – "Pearlite" Structure of Heat Treated Alloy. Reheated at 1100° F. after annealing and quenching. Etched in $K_2Cr_2O_7$; 100×

Workability

Copper-titanium alloys can be readily hot and cold worked *when prepared in a high-purity form.* During melting and casting, the alloy must be protected from contact with air. Even more important, a high-purity oxygen-free copper must be used as a starting material. We proved this by making alloys from the four types of copper shown in Table I; each contained about 4.3% Ti. After machining about ¼ in. from the diameter of the 1.3-in. rod, each alloy was preheated for 2 hr. at 1650° F., then hot rolled to reduce the cross sectional area 10 to 20% in each pass.

Alloys prepared from oxy-

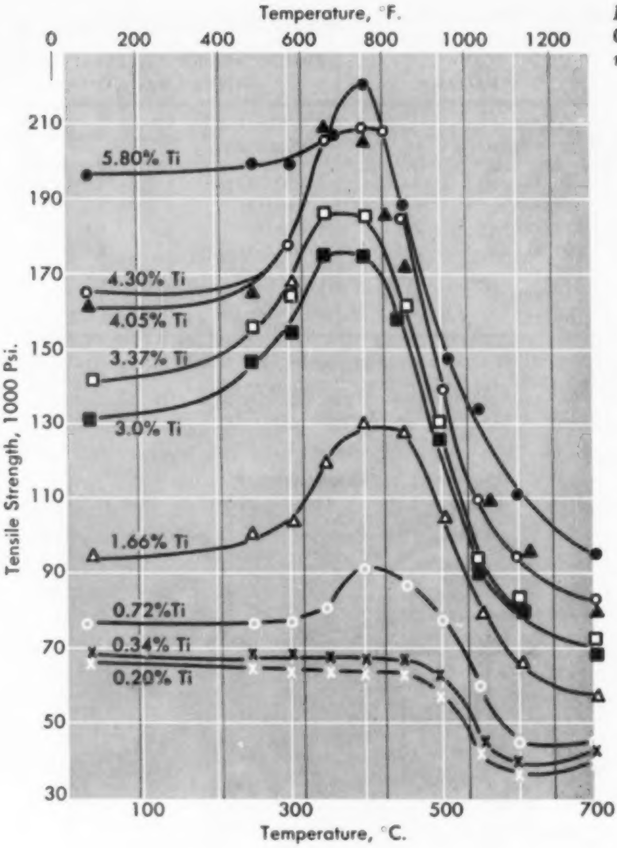


Fig. 4 – Effect of Aging on Several Copper-Titanium Alloys. These alloys were cold drawn 84% and aged 2 hr.

range increases. Alloys containing more than 5.8% Ti could not be hot rolled without cracking. Below 5.8%, hot working becomes progressively less difficult, and below 3% Ti, no cracking takes place regardless of the temperature used.

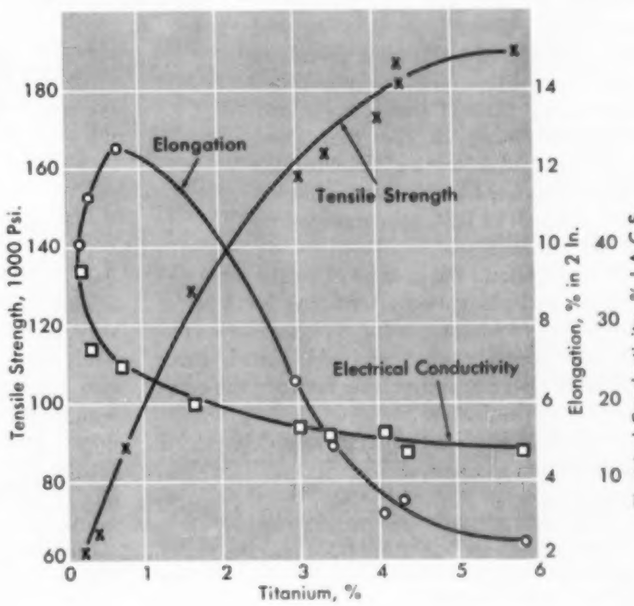
A 9-in. length of 4 by 4-in. wire bar containing 4.3% Ti was hot forged to a 2 by 2-in. bar without difficulty. However, since the cast crystals in the center were not completely deformed, further reduction is necessary to produce a homogeneous recrystallized structure.

Copper-titanium alloys can be cold worked extensively without cracking if they are first solution annealed. After such a treatment, 0.250-in. and smaller gage material can be cold worked over 90% without failure. This ability to absorb large amounts of cold deformation is important because work hardening contributes more to strength than precipitation hardening. Table II compares hardening treatments for the 4.3% Ti alloy.

gen-free high-purity copper could be hot rolled down to the desired 0.285-in. gage without difficulty. However, alloys prepared from the other types of copper exhibited surface cracking during the first pass, and frequently split down the center on the second pass. A microscopic study showed relatively few inclusions in the oxygen-free copper alloys, but many inclusions were observed in the other alloys. These inclusions evidently are formed as a result of the reaction between titanium and various impurities in the copper base.

In general, the hot working region of alloys containing up to 6.13% Ti extends from the solidus temperature to about 200° F. below the solvus temperature. As titanium lessens, the hot working

Fig. 5 – Properties of Copper-Titanium Alloys Aged at 850° F.



The response of these alloys to aging at various temperatures is shown in Fig. 4. All alloys were solution annealed for 2 hr. at 1650° F., quenched and cold drawn 84% prior to aging. The 0.20 and 0.34% Ti alloys give no indication of precipitation, and the others attain their maximum strength after heating at about 750° F. This optimum aging temperature is about 200° F. higher than that used in aging other very high-strength copper alloys.

Table II – Effects of Working and Precipitation Hardening

Cold Drawing	As Drawn		Precipitation Heat Treatment* After Drawing	
	Tensile Strength	Elongation	Tensile Strength	Elongation
0%	70,000 psi.	33.0%	130,000 psi.	16.0%
23	93,000	4.0	140,000	9.5
39	112,000	2.5	153,000	5.5
53	140,000	2.0	166,000	4.0
75	164,000	1.8	197,000	1.0
85	152,000-164,000	nil	210,000	nil

*2-hr. treatment at temperature giving highest tensile strength: for 0% cold drawing — 870° F.; 23% — 840° F.; 39% — 840° F.; 53% — 800° F.; 75% — 750° F.; 85% — 750° F.

Results of Overaging

Elongation and electrical conductivities were determined after aging at 750° F. Though the high strengths were impressive, improved ductility was desired so we tried overaging and found that 5 hr. or more at 750° F. was necessary to obtain significant elongation values. An even greater increase can be obtained by treating for 2 hr. at 850° F. instead of 750° F. A summary of the resultant properties is shown in Fig. 5.

Other Properties

All of the properties previously reported were determined on wire specimens cold drawn from 0.285-in. rod. For further study, the most promising alloy composition, 4.3% Ti, was rolled into sheet. Since, through slight misalignment, many of the thin sheet specimens had a "tearing" fracture, the values determined were somewhat erratic and are, at best, minimum values for this alloy.

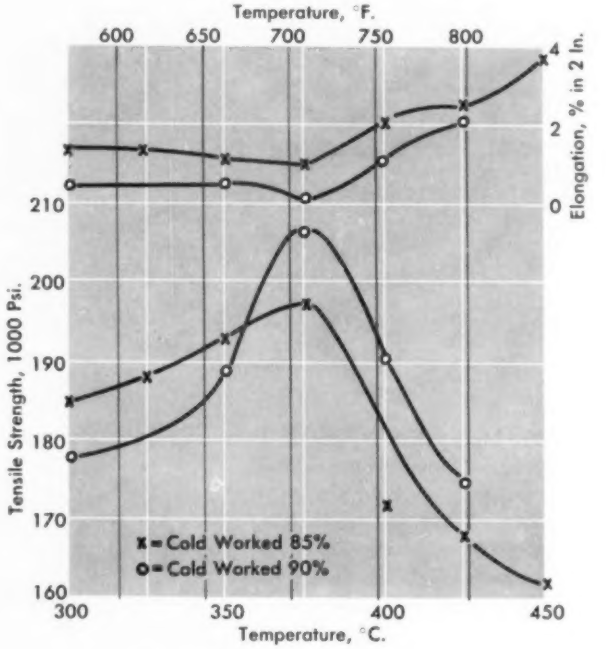


Fig. 6 – Effect of Aging on Properties of Cold Rolled Alloy Sheet

Figure 6 shows the change in tensile strength and elongation after aging for 2 hr. at a series of temperatures for 85% and 94% cold rolling. Longer aging of cold rolled sheet at 700° F. does not appreciably improve the combination of properties.

Several other characteristics were determined for this alloy, as follows:

Specific gravity	8.59
Modulus of elasticity *	18,500,000 psi.
Fatigue endurance limit *	41,000 psi., 10^7 cycles
Charpy impact strength *	12 ft-lb.
Charpy impact strength †	5 ft-lb.

This investigation proves that titanium is a very potent strengthener of copper. The relatively high aging temperature (750 to 850° F.) also indicates that these alloys have good high-temperature strength and stability. Fatigue and impact strength are also promising.

* Solution annealed 2 hr. at 1650° F., quenched, cold drawn 56%, aged 2 hr. at 800° F. (160,000 psi. tensile strength).

† Solution annealed 2 hr. at 1650° F., quenched, cold drawn 75%, aged 4 hr. at 750° F. (190,000 psi. tensile strength).

Light Metallurgy

*The Birth of an Alloy**

(The scene opens with the metallurgist seated at his desk. His secretary enters with the morning mail and places it before him.)

SECRETARY: Good morning, Mr. Scott, here is the morning mail.

METALLURGIST: Thank you. *(Does not look up.)*

(Exit Secretary. Metallurgist opens the first letter and reads it quickly to himself.)

MET.: Holy cats! I told them ten years ago that we should be working on this. *(Calls)* Mary, please have those two new experts on high-temperature alloys come into my office.

SECRETARY: *(Off stage)* Yes, Sir.

(Metallurgist continues to read letter and pencil notes. Expert No. 1 and Expert No. 2 enter.)

EXPERTS *(in unison):* Good morning, Sir.

MET.: Hi! *(Gives wave of hand)* I have just received a letter from our jet engine division. They say they are in desperate need of a better material for turbine disks. If we don't come up with a new alloy, they say they will close down the plant and all go back to farming. We all know how much overproduction we have on the farms, so you can see how serious this problem is. *(Experts nod agreement.)* This engine is very top secret, so they have classified the top operating temperature they need. The creep-rupture life and stress requirements are also classified! The only thing they will tell us is that we can't use any strategic material. *(Experts show agony as the requirements are given.)* Well, boys, there is the problem. What shall we do?

EX. 1: Let's start at the beginning and find a name for the alloy.

EX. 2: Good idea! *(Pause)* Since they want it to operate at such a high temperature, how about calling it "Helloy"?

EX. 1: That's the best name for an alloy I have heard yet, but you know it would never get by the company censors . . . How about calling it "Hoypaloy"?

EX. 2: Excellent! That has real mass appeal!

MET: *(Sarcastically)* Now that we have that settled, how are we going to get a material that is strong enough to suit those . . .

EX. 2: They say those new dislocations are what make a metal strong. Could we make up an alloy using only dislocations?

MET: *(To Expert 1.)* How about that? I gave you a paper to review just the other day concerned with dislocations.

EX. 1: I went over the paper, but the author keeps confusing the issue with mathematics. I did find something in a medical book, though, which explains dislocations in a much clearer manner. They appear to be very undesirable from what I read there. So I believe we should try and cast up an alloy with everything located. Might even call it "Localoy".

MET: That looks like too long an approach. It would have whiskers by the time we completed that project.

EX. 2: I still think I had a good idea to use nothing but dislocations. We could call it "Dislocaloy". *(Turning to Expert No. 1)* Why don't we work together on the project? You can use the metal I throw out and I'll use the dislocations you throw out.

MET: Now wait a minute! We're losing sight of the problem.

EX. 1: I'll see you at lunch. I have to hurry and enter this new alloy in the Patent Disclosure Book. *(Exit Experts 1 and 2)*

MET: All some guys can think of are those patent awards! Guess I'll have to get busy and do this job myself. This problem calls for a new research technique. *(Walks to file cabinet.)* Let's see. They want a new alloy for turbine disks. *(He opens file drawer labeled "DIE to DO". He removes special dice from the drawer, puts them in a large beaker, and shakes them as he walks to the table. As dice are thrown he says):* Come on, Dolly, how much moly? *(Observes dice)* Ah, 3%! *(End of Scene)*

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*A dinner in honor of Howard Scott was given by his associates of Westinghouse Electric Corp. on his retirement (see p. 120), and among the postprandial high jinks was a skit entitled "GLIMPSES of HOWard" wherein the various scenes gave a new and fanciful insight into his unique methods of developing such things as thermostatic bimetals, armor-piercing shot, gas-turbine parts (Discaloy), glass-to-metal seals (Kovar). The third scene, written by T. W. Eichelberger, research engineer in the research laboratories' metallurgy department, is reproduced here.

Steel Strip From Ore Without Melting

A PROCESS FOR MAKING steel strip from iron powder is the latest technical development in the fight against rising capital equipment costs of new steelmaking facilities of the conventional type. The new method, announced by Republic Steel Corp., Cleveland, at the dedication of its Research Center, also has the potential to reduce production costs. In the new process, strip steel is produced from iron ore without melting; normal production operations in coke ovens, blast furnaces, openhearths and blooming mills are bypassed.

The Republic process consists of three major steps which are illustrated in Fig. 1. First, iron ore is purified and then reduced to iron powder. The powder is funneled between four rolls where it is compressed into a semisolid strip with sufficient "green" strength to hold together. The compacted strip is heated to 2200° F. in a furnace with a reducing atmosphere and is passed through a series of hot rolling mills. Hot rolling brings the compacted powder up to full density and gives hot rolled steel which has the same quality as conventionally made steels. After coiling, the steel goes through the usual operations of pickling, cold rolling and annealing before being re-coiled or cut into sheets. The test stamping at the bottom of the photo in Fig. 1 shows that strip made from powder withstands severe die forming without tearing or cracking.

Republic has produced more than 1800 lb. of steel strip by the process. Plans are being made for a pilot line which will produce strip up to 12 in. wide on a continuous basis starting with powder. A model of the equipment is shown in Fig. 2.

Fig. 1 – The Sequence of Operations Which Produces High-Quality Drawing Steel From Iron Powder. Iron powder is compressed into semisolid (green) strip. This is hot rolled, pickled and cold rolled to give conventional strip with good formability as demonstrated in the test stamping

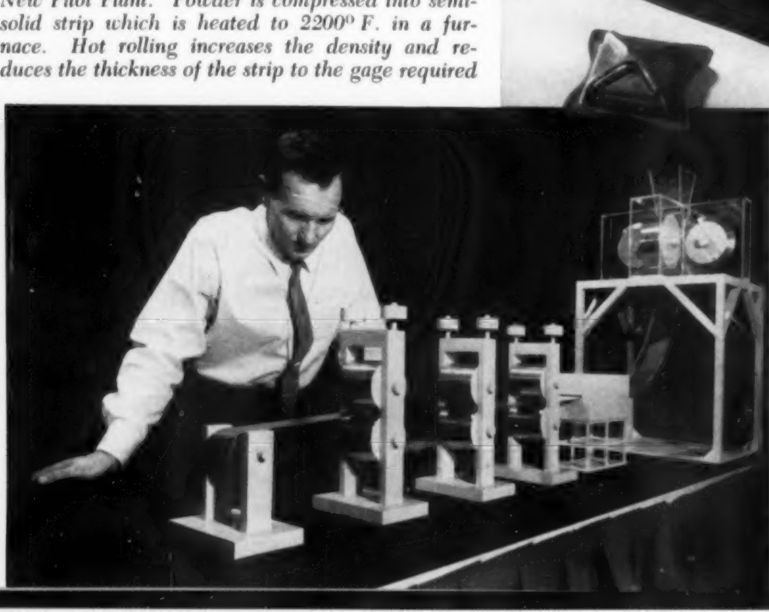


Fig. 2 – Model Illustrates Operations for Continuous Strip Production Which Will Be Embodied in New Pilot Plant. Powder is compressed into semisolid strip which is heated to 2200° F. in a furnace. Hot rolling increases the density and reduces the thickness of the strip to the gage required

TTS Diagrams for Types 304L and 316L Stainless

*By HILMER F. EBLING and MERRILL A. SCHEIL**

Studies of three types of widely used stainless steels after being reheated or aged for varying times at various temperatures show that their corrosion rates vary widely, and that true "stabilization" may be impracticable by commercial heat treatments. (R11, R2h; SS)

In an article published last month in *Metal Progress* (p. 94) entitled "Corrosion Resistance of Type 347 Stainless After 'Sensitizing' Heat Treatments", the authors presented the results of a systematic study of the relationship of prior metallurgical history (annealing, stabilizing and sensitizing heat treatments) on two commercial heats of 18-8 Cb stainless steel sheet. The results could be assembled in diagrams somewhat similar to the well-known TTT (time-temperature-transformation) diagrams prepared for the various engineering steels, and we have called them TTS (time-temperature-sensitization) diagrams. It was shown that in spite of the intended stabilization by the columbium addition, mill-annealed sheet can be eventually

*Mr. Ebling is research engineer in the metallurgical research department and Mr. Scheil is director of metallurgical research of A. O. Smith Corp., Milwaukee, Wis. This article is the second part of a presentation made before the U. S. Atomic Energy Commission's Welding Committee at its meeting in Richland, Wash., Oct. 13, 1958.

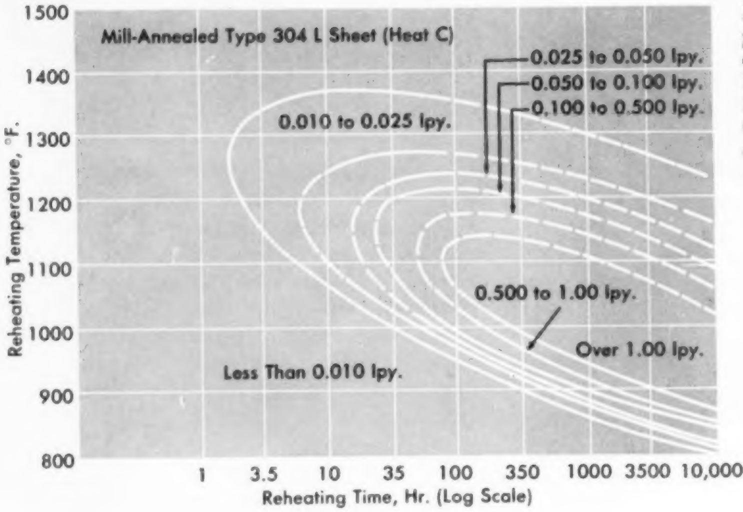


Fig. 1 – TTS (Time-Temperature-Sensitization) Diagram for Heat C of Type 304 L Stainless Sheet in Mill-Annealed Condition. Corrosion rates determined by Huey test – boiling nitric acid

sensitized at any particular temperature above 900° F. (probably at the lower temperature also) and the material will reach a maximum in sensitization at a characteristic time. After this peak is reached and the steel is held at temperature longer and longer, the metal will proceed through a "self-healing" stage and true stabilization will occur. It has been shown that a prior stabilization heat treatment of 1650° F. for 2 hr. at heat greatly reduces the maximum sensitization stage which occurs on the commercially annealed Type 347 stainless.

In the present article we will present the results of similar experiments with two heats (C and D) of Type 304 L and two heats (E and F) of Type 316 L. Their analyses follow:

Element	Type 304 L Heat C	Type 304 L Heat D	Type 316 L Heat E	Type 316 L Heat F
Carbon	0.022	0.026	0.024	0.023
Manganese	1.04	0.72	1.54	1.40
Phosphorus	0.021	0.020	0.018	0.018
Sulphur	0.018	0.020	0.018	0.013
Silicon	0.34	0.34	0.30	0.32
Chromium	19.31	18.38	18.14	18.42
Nickel	9.39	9.41	13.43	12.62
Molybdenum	——	——	2.50	3.00
Nitrogen	0.053	0.013	0.030	0.020

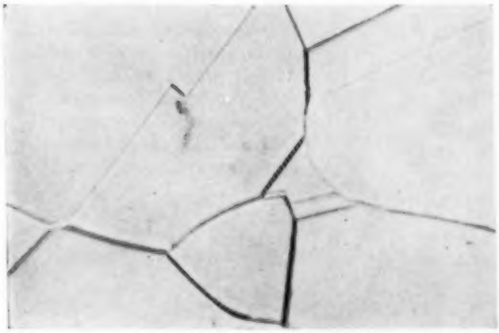
Type 304 L

The first commercial heats of Type 304 L were produced shortly after World War II. However, it was not until the acute shortage of columbium which occurred after the Korean conflict that the very low-carbon Type 304 L was recognized as material competitive to Type 347 stainless. It was not very long before metallurgists found that it was often easier to weld, and no apparent heat-affected zone would be found. (At this time there was some concern about the "knife-line attack" in welded Type 347 stainless.)

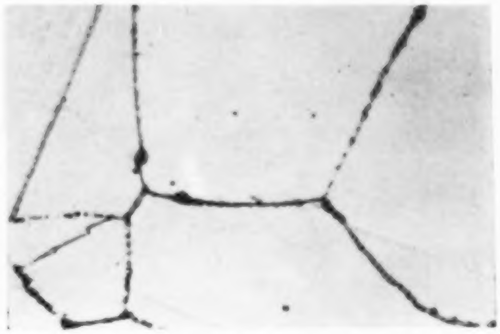
The two heats of 304 L used in our aging experiments were again chosen at random from heats supplied by different producers. As before, the test material was commercially annealed 12-g. sheet with 2D finish. Aging treatments and corrosion tests were carried out similarly – in fact, simultaneously – with the Type 347 specimens. From the corrosion data, it was noted that at 700 and 800° F. there is no sensitization up to heatings for 10,000 hr. At 900° F. sensitization occurs between 350 and 1000 hr., and at 1000° F. between 35 and 100 hr. At temperatures of 1300, 1400 and 1500° F., corrosion rates are of a low order for the times tested (100 hr.).

Heat D of Type 304 L follows a very similar pattern. The only differences in corrosion rates to be noted from Heat C are the lower corrosion rate occurring at 1000° F. after 100 hr. (which is 0.025 ipy. compared to 0.227 for Heat C) and at 1100° F. after 35 hr. (which is 0.030 ipy. compared to 0.440 for Heat C).

From the data for Heat C, which appears to have the lesser resistance to intergranular attack, a time-temperature-sensitization diagram was constructed, as shown in Fig. 1. This shows, in comparison with the curves in the previous article on Type 347, an increase in intergranular



Mill-Annealed; 0.006 Ipy.



Heated 10,000 Hr. at 1000° F. 2.05 Ipy.

Fig. 2 – Microstructure of Type 304 L (Heat C). Etched in aqua regia plus cupric chloride. 1000 ×

corrosion resistance for the short-time exposures. That is, the curves are shifted to the right. On the other hand, it is noted that the curves are more closely packed, which indicates that, once started, sensitization occurs much more rapidly than in Type 347. As far as this heat is concerned, aging at 1400° F. for the time tested (100 hr.) did not result in any loss of corrosion resistance. Aging at 1300° F. showed only a slight loss in corrosion resistance (0.016 ipy. max. at 100 hr.) and even at 1200° F. it required about 7 hr. at temperature to exceed a corrosion rate of 0.050 ipy.

If one arbitrarily chose 1200° F. for 1 or 2 hr. as a sensitization heat treatment to characterize the corrosion resistance of Type 304 L heats, both of them would look very good when compared to Type 347. However, it is a mistake to assume that the corrosion resistance of Type 304 L will be better than Type 347 after exposure to lower temperatures for longer times. As an example, in Heat C a sensitization heat treatment of 1200° F. for 2 hr. will result in a corrosion rate of 0.010 ipy. compared to 0.050 ipy. for Type 347 (Heat B) in the same condition. At 1050° F. about 100 hr. increases the corrosion rate to about 1 ipy. on Heat C, whereas under the same conditions Type 347, Heat B, would have a rate of about 0.2 ipy.

Again, if this corrosion pattern is found to be characteristic for all heats of Type 304 L, it will be possible to construct a diagram for a particular heat by calculation from the chemistry, or from a few corrosion tests of well-chosen time-temperature relationships.

"Stabilization" of Type 304 L for 2 hr. at 1650° F. is not of any benefit. As a matter of fact, the corrosion tests show that sensitization then occurs after shorter exposure to the temperatures below 1100° F. For example, in the annealed stock, Heat D, the 10,000-hr. exposure at 700° F. caused no extra corrosion (0.007 ipy.) but this jumped to 0.044 ipy. for the "stabilized" stock; after 10,000 hr. at 800° F., it was 0.010 ipy. in the annealed sheet compared to the 0.064 ipy. in the "stabilized". From the few tests made, it appears unlikely that any simple heat treatment will be an effective stabilizer against intergranular attack.

The microstructure of Type 304 L is shown in Fig. 2. At left the annealed stock shows no grain-boundary constituents. This microstructure is also typical of the material after the stabilizing heat treatment. At right is the sensitized structure (aged at 1000° F. for 10,000 hr.) showing that the grain boundaries are badly attacked by the etchant. Microstructures of the specimens with intermediate corrosion rates show a lesser degree of attack, with discontinuous grain-boundary networks.

From what was seen of the intergranular corrosion resistance of Type 304 L, it is apparent that this material will successfully resist sensitization from the normal short-time fabricating heat treatments. Beyond this, the material has no further advantage over Type 347 stainless. As much as is known at present, Type 304 L should not be substituted for Type 347 since it cannot be stabilized by heat treatment. On the other hand, Type 347 is not much better than Type 304 L if used in the commercial annealed condition.

Type 316 L

Low-carbon heats of Type 316 were also made commercially shortly after World War II, and

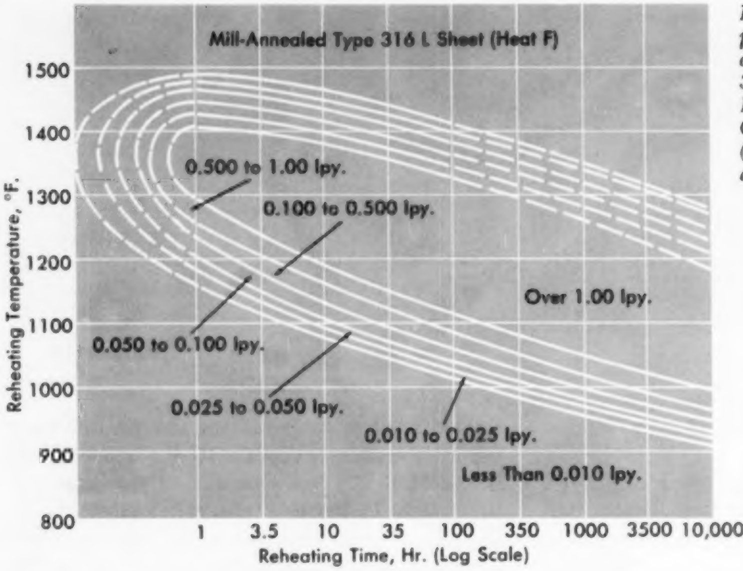


Fig. 3 – TTS (Time-Temperature-Sensitization) Diagram for Heat F of Type 316 L Stainless Sheet in Mill-Annealed Condition. Corrosion rates after aging (reheating) for times and temperatures noted

it is considered to have the best resistance to corrosion in service of all the 18-8's. The molybdenum addition increases resistance to pitting, sulphuric and sulphurous acids, and to neutral chloride solutions. However, it is not immune to intergranular attack in the nitric acid test.

The two heats of Type 316 L used by us in this investigation were from the same producer. As before, both heats were commercial 12-g. sheet, mill-annealed, pickled and furnished with a 2D finish.

Heat E is quite resistant to damage by aging up to 10,000 hr. at 900° F. and up to 350 hr. at 1000° F., but the corrosion rates are quite high after exposure to 1200 and 1300° F. The same pattern is established in Heat F as with the exceptionally slow sensitization at 900° F. up to 10,000 hr. High corrosion also results from exposure to 1200 and 1300° F. Isothermal stabilization occurs during heating at 1400° F. After 1 hr., a corrosion rate of over 2 ipy. on Heat F was obtained. This dropped to 0.58 ipy. after heating 3.5 hr., to 0.23 after 10 hr. and further reduced to 0.015 ipy. after the time was extended to 35 hr.

A time-temperature-sensitization diagram for Heat F is shown in Fig. 3. Comparing this to the previous diagrams, it is immediately noticed that the curves lie about 100° above those for Types 304 L and 347. The curves are closely packed and lie much further to the left. This, then, shortens the heating schedules which cause corrosion rates over 1 ipy. to less than 1 hr. at temperatures between 1300 and 1400° F.

Even at 1200° F. corrosion rates would be in the range of 0.1 ipy. after 1 to 2 hr. While this temperature would be ideal to establish benchmarks for constructing similar diagrams, it is not a good temperature to use arbitrarily for some corrosion specification. This is one factor which underlies some of the controversies over the use of the boiling nitric acid test. The 1200° F. sensitization temperature used for characterizing corrosion resistance of all 18-8 alloys (and, in particular, Type 316 L) has no reasonable explanation in light of the information presented in this paper.

In order to determine the effect of a stabilizing heat treatment, aging and corrosion tests were made on sheet which had been heated to 1650° F., held for 2 hr. and cooled at a rate equivalent to a 0.75-in. plate. There were very little differences between these corrosion rates and those obtained on the original commercially annealed material. It thus appears doubtful that a prior stabilizing heat treatment would have a beneficial effect on Type 316 L.

Microstructures are shown in Fig. 4. At top is the typical structure of the commercially annealed sheet, showing no apparent grain boundary constituents. In the sensitized condition (Micro B) a fine precipitate is seen; it is not known whether this is carbide or sigma phase. However, after stabilizing at 1650° F. for 2 hr.,

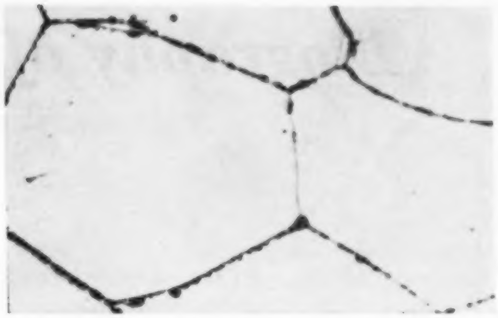
A – Heat F, Mill-Annealed; 0.005 Ipy.

Fig. 4 – Typical Microstructures of Type 316 L. Etched in aqua regia with cupric chloride; 1000 ×

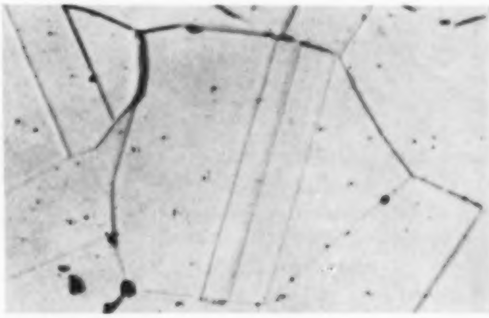
a difference was noted between the two heats. Heat E (Micro C) has very little grain-boundary constituent, whereas Heat F (Micro D) developed a considerable amount, presumably sigma; this constituent does not affect the intergranular corrosion resistance because it occurs as fairly large particles which do not form a continuous network. Furthermore, the temperature at which this phase was formed (1650° F.) is high enough to allow the chromium to diffuse rapidly into the depleted area adjacent to the new phase. Micro E represents commercially annealed stock of Heat E after being aged at 1400° F. for 100 hr. It now also shows large particles of sigma phase at the grain boundary, and the corrosion resistance is also of a low order.

Summary

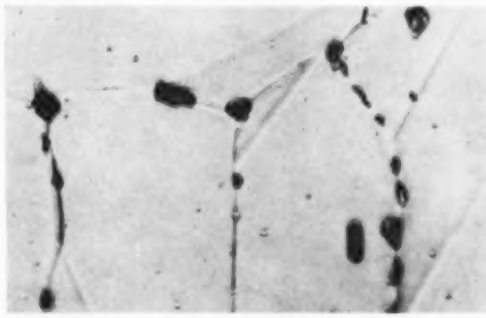
In this investigation, described in this and the previous article, we have attempted to survey the resistance to intergranular attack by three types of chromium-nickel stainless steels. Time-temperature-sensitization diagrams have been constructed for each of them, revealing the effect of time and reheating or aging temperature on the corrosion rate in boiling nitric acid – a very searching test, in our opinion. These diagrams are distinctly different for each type of steel. If, upon further work involving many more heats of each material, it will be found that these patterns persist, each type of stainless steel could be characterized by such a diagram. Such a general knowledge of the intergranular corrosion resistance of stainless steels would prevent the metallurgist or designer from being trapped by the result of a single test on a given heat of material.



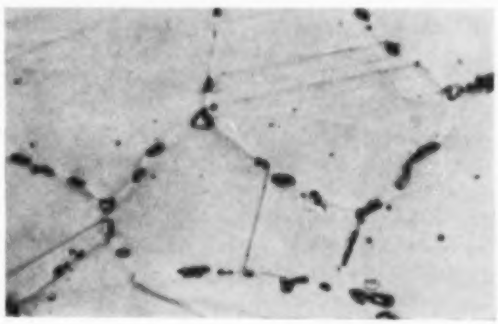
B – Heat E, Aged 10,000 Hr. at 1000° F.; 2.29 Ipy.



C – Heat E, Stabilized 2 Hr. at 1650° F.; 0.007 Ipy.



D – Heat F, Stabilized 2 Hr. at 1650° F.; 0.006 Ipy.



E – Heat E, Mill-Annealed, Aged 100 Hr. at 1400° F.; 0.012 Ipy.

Biography of an Eminent Living

Roy Harrison Ledbetter

Metallurgist

From college graduation to retirement nearly 50 years later, Roy Harrison Ledbetter served one company – Tennessee Coal, Iron and Railroad Co. in Ensley, Ala. – with a wholehearted interest and singleness of purpose.

Roy grew up in Anniston, not far from Ensley, and attended the University of Alabama, graduating in 1906 with a bachelor of science degree in chemistry. Immediately after graduation, he began his industrial career in the chemical laboratory of Tennessee Coal, Iron and Railroad Co., acquired by U. S. Steel Corp. in 1907 and now a division and subsidiary of the corporation. In a little over a year, he had charge of the laboratory of the Alice blast furnace in Birmingham.

Three years later, only 23 years old, he became superintendent of the furnace until a business recession forced a temporary shutdown and he was transferred to the Ensley blast furnace. In 1912, when business picked up again, the company decided to reactivate the Oxmoor furnace, and Roy Ledbetter was assigned the job of rebuilding and operating the furnace. Given a chance to show his mettle, Roy made an outstanding record in both quality of iron and economy of production, and his ability as a blast furnace operator became widely recognized.

Then in 1916 he was put in charge of the company's Bessemer, Ala., blast furnace, where he developed a method of making pig iron from 100% scrap for metallics and of making a slag from dolomite and silica gravel. At this time, there was plenty of scrap in the South and this method of producing mold iron was much more economical than the former importation of low-phosphorus iron from the North for making ingot molds.

After eight years as superintendent of the Oxmoor and Bessemer furnaces, he went back to Ensley as superintendent of the six Ensley blast furnaces. In 1930 he became general superintendent of the Ensley Works and three years later was made general superintendent of the Fairfield Steel Works. In 1936 Roy assumed the position he held until his retirement – manager of the department of metallurgy, inspection and research. For several years he supervised all products manufactured, and was responsible for all development and research; he thus gained a wide acquaintance throughout the South with steel consumers and their problems.

His years of experience with Southern blast furnaces have made Roy Ledbetter a pre-eminent authority on blast furnaces, particularly under Southern operating conditions. He has to his credit a long list of inventions, one of which is the well-known "Ledbetter tuyere", as well as innumerable unpatented innovations and ideas that were adopted by his company.

Many of his inventions were designed to improve blast furnace operation. He originated the direct blast furnace metal process for ingot molds using a mixture of molten iron and 20% blown metal from a bessemer converter. The installation of ship channel guides for the pony trucks on skip tracks was his idea and he perfected steel hot blast valves as a substitute for bronze valves which required frequent replacement under dirty gas conditions. He also originated the relocation of bustle pipes to give better access to the bosh, and designed shields for tuyeres for safety.

Other innovations included a steel twist guide for billet mills, with a renewable facing made with a wear resisting nickel-manganese steel – a vast improvement over cast iron guides – and a one-piece hot blast valve packing which has no threaded parts to become loose and out of adjustment. He was the first to institute mechanical handling of ferromanganese by casting directly in removable boxes on railroad cars, thus eliminating the danger and labor of breaking with sledges.

Roy has two main interests – the steel business and the stock market – and he has been very successful in both.

Since his so-called retirement seven years ago, Roy Ledbetter's knowledge of blast furnace practices has been put to good use for he has been serving as a consultant for many Southern metallurgical industries.

E. C. Wright

Lithium . . . the Lightest Metal

*By F. B. LITTON**

LITHIUM IS THE LIGHTEST METAL known. But for its softness and high reactivity (Fig. 1), it would undoubtedly be considered for a structural material in aircraft today. As it is, aluminum alloys containing appreciable amounts of lithium are being developed now, and are quite likely to be in production soon. Lithium aids in other ways, too. It increases the mechanical properties of steel, nickel, aluminum and other metals, and is a convenient grain refiner for zinc, aluminum and copper alloys. Furthermore, its high reactivity becomes an advantage in removing oxygen and sulphur from molten metals.

Since lithium is a comparatively new arrival on the metals scene, little is known about its quantitative effects. However, enough information has been revealed by laboratory work to indicate that the metal is definitely of value in many applications. If nothing else, its unique lightness and the many unusual properties deriving from the small and mobile lithium ion are interesting features.

Properties and Production

Aside from its lightness (half as heavy as water, it floats on gasoline), lithium has other unusual properties. It is softer and easier to work than lead, and has a larger heat capacity than any other substance except water, which it equals. A silvery luster is apparent when the metal is freshly cut, but tarnishing occurs in a short time in ordinary atmospheres.

Lithium's high reactivity makes extraction from its ores fairly difficult. In current methods, the ore – spodumene from pegmatites, in this country – is produced to form a water-soluble salt, lithium hydroxide. Lithium chloride, obtained from the hydroxide, is then melted with another salt (potassium chloride), added to lower the melting point, and electrolyzed. Figure 2 illustrates lithium being poured. Though purity of the metal depends on purity of the salt, commercial practice produces 99.8% pure lithium.

Chemically, lithium is quite active, though not as reactive as the other elements in Group I. It combines readily with hydrogen, oxygen, nitrogen and the halogens. Potentially, it is an excellent scavenger.

Aluminum-lithium alloys offer intriguing possibilities for airframes because of the potential structural lightening. Much research is being carried on now; in fact, one alloy is already in commercial use. That is X 2020 (see diagram in *Metal Progress,* April 1959, p. 96-K), a development of Alcoa.† Containing cadmium along

*Manager, Metallurgical Research, Research and Development Div., Foote Mineral Co., Philadelphia.

†EDITOR'S NOTE: An article in a forthcoming issue of *Metal Progress* will discuss the properties and fabrication of aluminum alloy X 2020.

Both the pure metal and its alloys, most of which are still in the laboratory stage, have unusual properties which can be useful. Its addition to other metals increases tensile strength and refines grain size. The metal's high reactivity makes it potentially a good scavenger in melts. (A-general; Li)

with lithium, the alloy is 3% lighter than conventional aluminum alloys. It is said to have a high modulus of elasticity (8% above that of aluminum) and to withstand temperatures up to 400° F.

The phase diagram (see data sheet, p. 96-B) indicates that aluminum-lithium alloys are age hardenable. Experimental work, in fact, has proven that this is true for alloys with over 2.8% Li. In one test, an alloy with 3.3% Li was quenched from 1025° F. The tensile strength was 36,700 psi. with elongation of 26% and hardness of Brinell 59.

Additions of lithium to magnesium change the crystal structure of the latter metal from close-packed hexagonal to body-centered cubic and thus improve the working properties of the alloys. Lithium in magnesium also lowers its density. Though the magnesium-lithium alloys are not difficult to prepare, high-purity lithium is needed because embrittlement results from very small amounts of sodium. They can be worked at 450° F., and cold reductions of 50% are possible.

Magnesium-lithium alloys have poor corrosion resistance and are subject to overaging. Consequently, much research has been devoted to complex alloys, the extra elements being added to correct these two defects. The phase diagram is shown on the data sheet, p. 96-B.

A small amount of lithium (about 0.05%) makes lead easier to cast. Furthermore, toughness, hardness, and tensile strength are improved without affecting the ductility. In Germany, a lead-lithium bearing alloy known as "Bahnmetall" has been used extensively on railway equipment. A typical sample contains, besides lead, 0.73% Ca, 0.58% Na and 0.04% Li. This alloy has a hardness of Brinell 34, compressive strength of 25,000 to 30,000 psi. at high temperatures, high resistance to deformation, and satisfactory wearing qualities.

Lithium has also been used to advantage in a eutectic alloy with lead, designed to shield an instrument from thermal neutrons and secondary gamma radiation. This alloy contains 0.69 wt. % of lithium, the balance being lead. It has unusually high strength, even at elevated temperatures. Other alloys can be used for cable sheaths and storage battery grids. The data sheet gives a Li-Pb phase diagram.

Though lithium has been used for degassing of copper, little has been published concerning phase relationships. What is known is illustrated on the data sheet. The Italian scientist, Pastorello, also mentioned that the alloys are readily attacked by water leaving pure copper. A copper alloy with a 1% Li addition has been used as a self-fluxing brazing alloy.

Lithium has been used with silicon for semi-

Fig. 1 – The Density of Lithium Is 0.534 G. per Ml., Consequently, It Floats on Water, Mineral Oil, Ether, and Gasoline. Though lithium decomposes in water (note the rising vapors), it does not ignite as do sodium and potassium

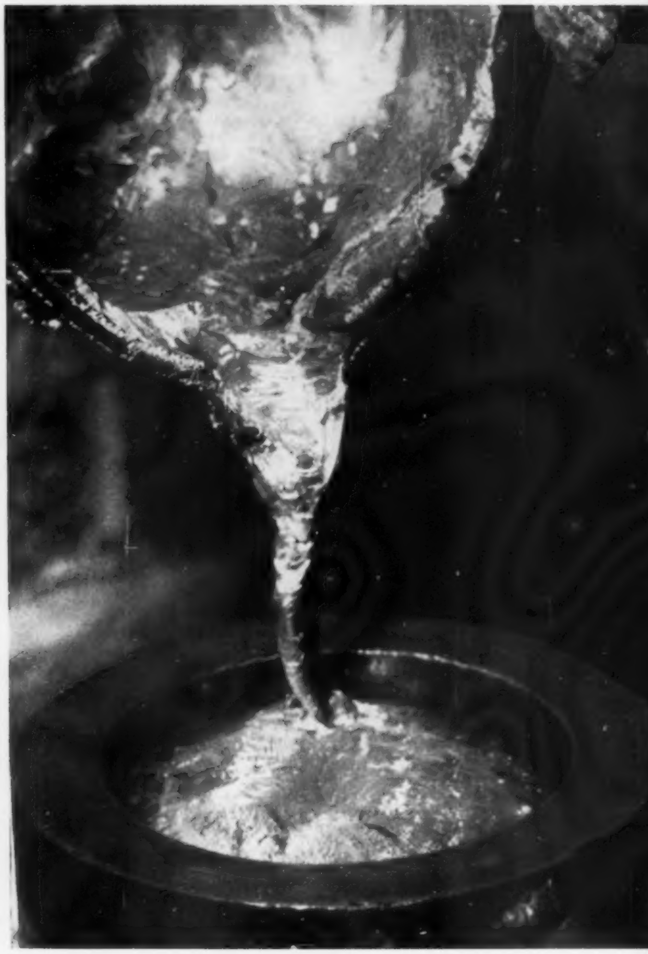


Fig. 2 – Lithium Metal Is Produced Electrolytically From a Fused Mixture of Lithium Chloride and Potassium Chloride. While still liquid, it is ladled from the bath and poured into molds

conductors, and with silver for soldering and brazing alloys. It is claimed that silver solders with lithium have better fluidity and wetting action than those without lithium. Some interest has also been shown in lithium as a fluxing agent in self-fluxing silver brazing alloys.

The addition of 0.6% Li to zinc produced 62,000 to 65,000 psi. tensile strength and freedom from porosity in die castings, according to one investigation.

Lithium in the Future

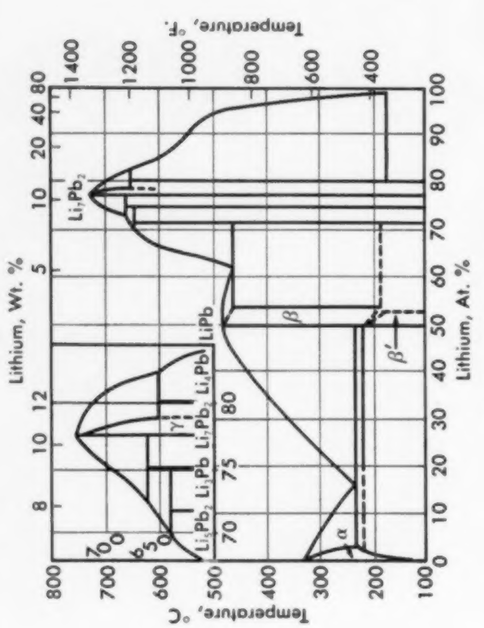
The ever-increasing interest in high-speed flight will inevitably result in a growing demand for light-weight materials, and the use of lithium in structural alloys is one logical approach. Because its density is significantly lower than that of any other solid element, lithium additions will reduce the density of any alloy of which it is a component.

Special research projects on titanium-lithium and beryllium-lithium alloys indicate that for such applications, cost is not a serious obstacle, and there is a possibility that commercially valuable alloys containing lithium may be developed, even where weight is not the significant property.

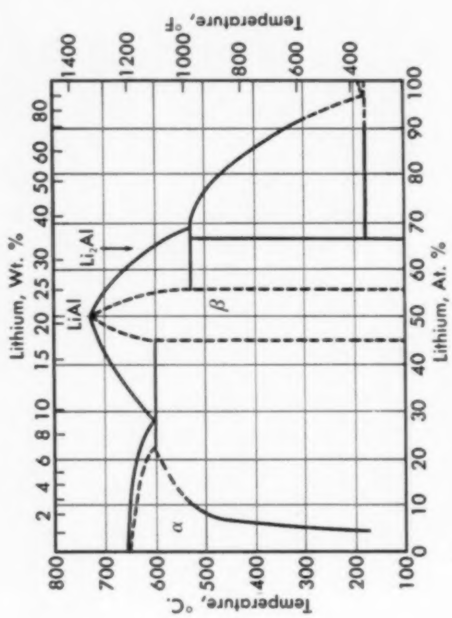
As the foregoing shows, lithium has many interesting possibilities. It should become more and more useful in the coming years.

Binary Phase Diagrams of Lithium

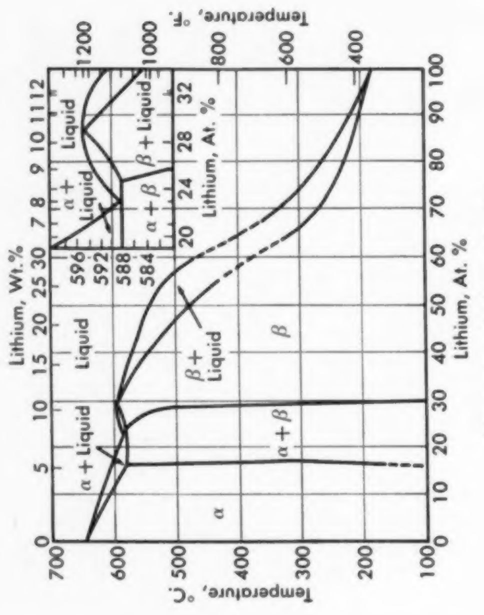
Source: Foote Mineral Co.



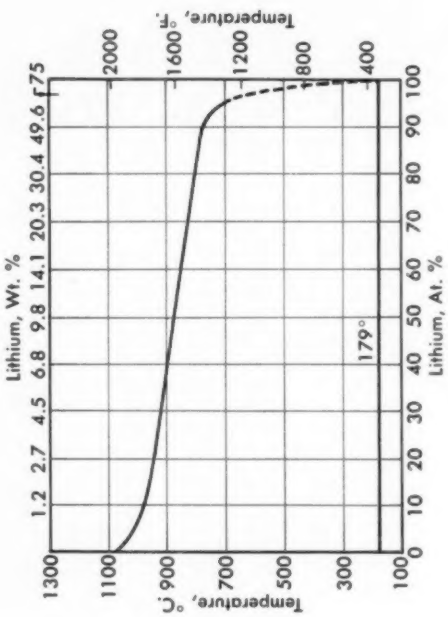
Lead-Lithium System



Aluminum-Lithium System



Magnesium-Lithium System



Copper-Lithium System

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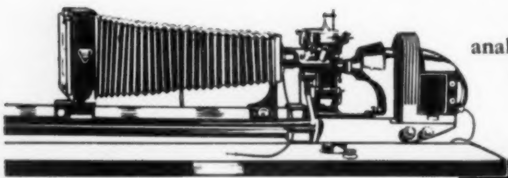

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New Techniques Broaden Forging Picture - I

*By J. H. JACKSON and H. B. GOODWIN**

Several new forging methods offer much promise. Of these, the counterblow hammer, the "impacter", the precision forging process, the "continuous grain flow" process and roll forging are discussed in this article. (F22, 1-52)

THERE ARE PLENTY of new forging developments on the horizon. Some of them are unproven or even controversial, but all give evidence that there is no stagnation in the forging industry. Recent years have seen these important developments:

- The counterblow hammer
- The "impacter"
- The GFM "precision forging" process
- The "continuous grain flow" process
- Acceptance of roll forging
- "Cored forging"
- Multiple ram technique
- High-energy forming

Aside from these new and improved forging processes, there has been much progress in conventional techniques. Hammers and presses continue to become more efficient, and better diemaking methods have appeared. It is plain that the forging industry is not standing still.

The first five of the forging developments noted above will be discussed in this article. The concluding article, next month, will discuss cored forgings, multiple ram techniques, high-energy forming, improvements in conventional equipment, and progress in fundamental research on the forging process.

The Counterblow Hammer

During the 1930's, the Germans introduced the counterblow hammer, and built about 350 of them to replace steam drop hammers. At that time, limited trials were made here with unsatisfactory results. American technical teams, which went into Germany after the war, found the Germans had progressively developed larger and larger counterblow hammers for making very heavy forgings. When a large hammer was brought here and installed at the Ladish Co., a heated debate began concerning whether or not this type of hammer is adaptable to American forging practice.

The counterblow hammer overcomes some of the factors that limit the power of conventional steam drop hammers. The latter can be built to about a 45,000 to 50,000-lb. rating†; counterblow hammers which can do the work of a ham-

*Mr. Jackson is manager and Mr. Goodwin is consultant, metallurgy department, Battelle Memorial Institute, Columbus, Ohio. This is the second of three articles concerning the present status of the forging industry. The first, published last month, discussed industrial trends that are likely to affect the forging industry.

†The rating of the conventional drop hammer is the "falling weight" or weight of the reciprocating parts. Since steam pressure aids in striking the blow, the actual hammer energy is about double that of a board drop hammer of the same nominal rating. While there is no easy way to compare capacity of hammers and presses, a 12,000-*lb.* hammer will make forgings that would require a 5000-*ton*, or larger, press. Counterblow hammers are rated in ft-lb.; dividing the counterblow hammer rating in ft-lb. by 8.5 gives the approximate equivalent drop hammer rating in pounds. This is based on drop hammer efficiency of 80% and striking velocity of 26 ft. per sec.


LADISH
L

Fig. 1 – This Counterblow Hammer Can Develop Over a Million Ft-Lb. of Energy and Produce Closed Die Forgings Weighing Over 20,000 Lb. According to Ladish, it has three times the capacity of any existing conventional single-action hammer

mer with a 100,000-lb. rating have been built.

In the counterblow hammer, the large inertia mass needed in the anvil block is eliminated. The lower die is mounted on a movable ram which moves counter to the upper ram and die. The two rams, synchronized by coupling systems, meet at the center of their combined travel, where the workpiece is held. Because both rams are the same weight and moving at the same speed, when they strike, the force of the blow is not transmitted to the foundations.

In a conventional hammer, from 10 to 30% of the force of the blow may be lost through the anvil into the foundations. The heavier the anvil, the less energy lost, but the greater the size and cost of the installation and foundations. Therefore, the anvil weight is a compromise. It is often around 18 to 20 times the hammer rating (this is known as the anvil ratio) which means that the largest hammers require anvils weighing some 800,000 lb. With constant anvil ratio, the proportion of lost energy appears to increase as hammer size increases. This fact, coupled with increased manufacturing, transportation and other difficulties associated with larger anvils, places a practical limit on the size of conventional hammers.

Another reason for limiting hammer size is the magnitude of earth shock and the distance which it travels. Both become so great that it is difficult to find locations where the hammer shock will not interfere with other operations. In addition, serious problems occur because oak fibers in the timbers (over concrete foundations) on which hammers are mounted break down. When this occurs, tilting of the anvil may result; this can, in turn, cause one-sided wear or breaking of the hammer guides.

The counterblow hammer is said to eliminate most of the difficulties. Furthermore, counterblow hammers forge the work equally on both sides; it is not necessary to turn the forging.

Critics point out that customary American practice is to forge the work progressively in several impressions in the same die, lifting the part by a tonghold and laying it in the appropriate impression in the bottom die. Because the bottom die moves, this practice cannot be followed with the counterblow hammer.

In contrast, European practice has customarily been to use the impression die hammer for final sizing only. Most of the preliminary shaping is done on other equipment – often flat die hammers. There are many large parts where progressive impressions are needed to make the stock flow properly, and it is questioned whether the counterblow hammer is suitable for any forging other than those simple enough to be made in single-impression dies. Operating speeds and possible mechanical difficulties are also criticized.

As yet, the counterblow hammer has not found any large place on the American scene. However, one U.S. company is now installing what will probably be the largest counterblow hammer ever constructed.

The Impacter

In the fall of 1952, Chambersburg Engineering Co. announced "impacting". According to claims, this new process makes it possible to produce many types of parts automatically.

Essentially, impacting is forging carried out in midair. Two opposed horizontal impellers, run by compressed air or steam, carry the forging dies. Their strokes are timed (by electronic controls) so that the two rams always come together in the same plane of impact. For forging, hot (or cold) stock is suspended between the dies and struck on both sides simultaneously. In a more recent modification, a finger supporting the stock is retracted just as the impellers come together leaving stock unsupported in midair just before it is struck.

Models are built for flat die forging. The operator may hold the stock with tongs as in conventional air and steam hammer forging, or cranes, manipulators and stock positioning devices can also be used.

Advantages of the process are:

1. Shock and vibration are largely eliminated because the two opposing impellers have equal momentum. No heavy foundation or anvil is needed.

2. Metal is worked uniformly because the stock is struck equally from both sides.

3. Efficiency is increased; nearly all the energy is absorbed in the workpiece. Less total energy is required than with other forging processes.

4. Contact between stock and dies lasts only a few thousandths of a second. This results in longer die life and easier forging because the piece is not chilled as much.

5. The working area may be readily enclosed

Fig. 2 – These Two Parts Have Been Produced by Rotary Forging. The smaller part is a main drive shaft which is forged from a 3¼-in. bar, 8 9/16 in. long. Finished length is 16½ in. The other piece is a landing gear component weighing 71 lb. Original billet was 14 in. long and 4¾ in. diameter. Both parts had been previously made by machining from bar stock

and a protective atmosphere provided.

6. Mechanical positioning is more accurate; less stock is required in forging blanks. Mechanical handling is also safer.

7. Automatic heating, feeding, forging, and discharging of stock are easy to arrange.

The GFM "Precision Forging" Process

Brought to perfection in Europe since World War II, a new forging concept known variously as "precision forging", "rotary forging", or the "GFM process" has recently been introduced in this country. The process got its start in wartime German experiments on cold forging the rifling into gun barrels.

In the basic machine, three, four or more hammers converge radially on the workpiece somewhat as they do in a rotary swaging machine. Equally spaced around the workpiece, they all strike it at the same time. The process differs from swaging in that the end-of-throw positions of the hammers are precisely controlled and can be varied during the forging process. In effect, each hammer is mounted on a solid connecting rod driven by an eccentric. Each eccentric is itself eccentrically mounted in a separate housing. By turning the housing, the entire hammer mechanism is moved inward or outward with respect to the central axis of the workpiece. If all housings are turned at once, all hammers move in or out together.

The outer shape of the forging (which can be cold or hot) comes from the shape and setting of the hammers. Hammer dies are generally simple in design and are easily changed. The workpiece is rotated to produce round shapes, but other cross sections may be produced without rotating the workpiece. The inside can be shaped by a suitable mandrel.

The workpiece is firmly held by a chucking head which feeds the work into the machine. Hammer settings and chucking head movement are positively controlled by a series of templets mounted on synchronized indexing drums. Thus, the forging cycle is usually completely automatic once the operator chucks the piece and pushes the starting button.

Vertical machines take stock up to 5 in. in diameter with forged lengths up to 48 in.; a horizontal machine which will forge 12-in. diameter stock in lengths up to 78 in. has been built. These machines can produce forces of 220 tons per hammer and operate at speeds of 600 strokes per min. An ingenious design prevents the forging forces from acting on the control system.

The two great advantages of the process are high precision and high speed. In regular pro-

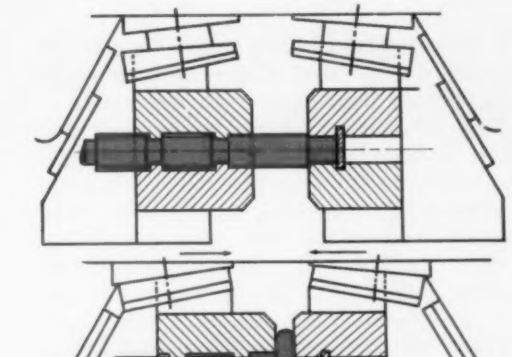


Fig. 3 – How the Continuous Grain Flow Process Works. At the top, the part is ready to be forged. Next, the jaws come together to make the flange. In the third and bottom diagram, the throw is formed. Action continues until the crankshaft is finished

duction, work is finished to these tolerances:

Hot ± 0.012 in. outside
± 0.004 in. inside (with mandrel)
Cold ± 0.004 in. outside
± 0.0004 in. inside (with mandrel)

Curtiss-Wright has forged in 40 sec. a workpiece having seven outside dimensions and four inside diameters plus tapering joints. Rocket nozzles have been forged in 30 sec. Heat exchanger tubes, venturi tubes and artillery shells have also been made by this process. Costs are often considerably below those of other forging methods. Figure 2 illustrates two parts produced by rotary forging.

The "Continuous Grain Flow" Process

Development of the "continuous grain flow" (or "CGF") process began in the 1930's. Difficulties met in forging locomotive axles at Aciéries de la Marine, Saint Chamond, France, led to its conception by M. Roederer, an official of the company, and parts of an experimental machine were built. Hidden during the German occupation, these were assembled after the liberation of France. Since the war, the process has been extensively developed in Europe.

This process is an extremely interesting example of the special forging method devised to solve a particular problem. Its principles and advantages can be understood by describing its operation in producing heavy crankshafts. In the CGF process, crankshafts are formed, one throw at a time (from bar stock or preformed bar) in a special forging machine which is positioned in a conventional hydraulic press. (See Fig. 3.) The upper member of the machine is attached to the moving crosshead of the press, and is built so that one downward stroke forms one crank throw. When placed in the machine, the heated stock is gripped firmly in three places, the two journals and the crank pin. As the crosshead descends, the outer grips (mounted on sliding cranks) move inward. The vertical movement of the crosshead produces horizontal movement of the outer grips through an inclined plane arrangement. The stock is upset between the outer and center grips. At a certain stage, the center grip moves down as the outer grips continue to move inward. Upset material then forms two webs of the crank. Since they are not held in at the periphery, they form an ellipitical shape by the natural flow of the metal.

With preformed bars used for larger cranks, no initial upsetting is needed, and the center and outer grips start to move at the same time. After the first crank throw is formed, the piece is moved and the operation repeated as often as needed to form additional crank throws. Only the portion of the bar to be forged is heated.

The advantages of the CGF process for making crankshafts are:

1. The fibers in the final forging are oriented to give maximum strength to the part, being parallel to the axis in the journals and pins, and perpendicular to the axis in the webs.

2. The central axis of the final forging corresponds to the central axis of the ingot. Thus, any unsound metal, which is most likely to be in

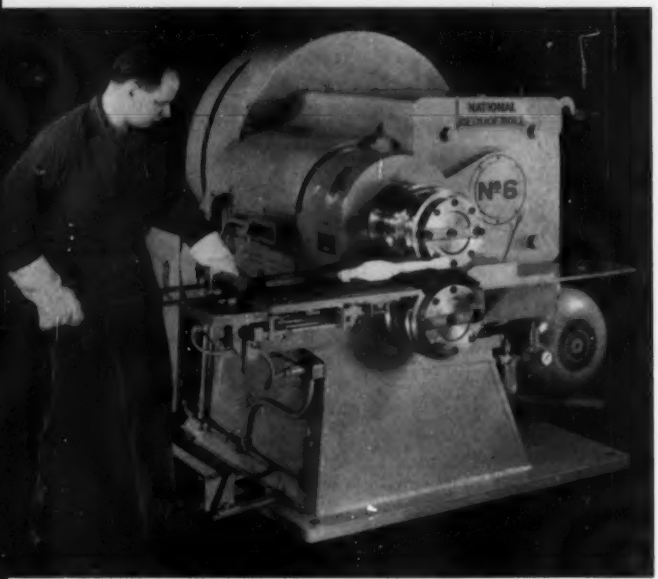


Fig. 4 – Roll Forging as It Is Practised Today. Pedals control starting, stopping, and reversal of rolls

the ingot center, winds up in the neutral axis of the forging.

3. Hot twisting, necessary after forging crankshafts in the conventional manner, is eliminated, since the various throws are initially formed in the correct angular relationship.

4. Metal is saved because much less has to be removed by machining. (One large shaft, formerly made from an 8-ton ingot, could be made from a 2¼-ton ingot by the CGF process.)

5. There are fewer rejects.

Small crankshafts are drop forged, and there is some debate over the size at which it becomes cheaper to use the CGF process. So far as technical practicality is concerned, the processes overlap. Other large parts can be forged economically by adaptations of the method.

Critics have emphasized its high capital cost and mechanical complexity. Furthermore, once the machine is installed in a press it takes considerable time to reconvert for normal forging operations. They also point out that specially equipped horizontal presses can upset large flanges even better than the CGF equipment. However, for certain applications the process seems quite useful.

Roll Forging Is Useful

In roll forging, in contrast to conventional rolling, the metal is worked only part of each roll turn. Instead of being round, the rolls are flattened on one side, giving clearance space between them during part of their revolution.

Originally, the rolls turned continuously and had to be large in diameter because a large gap was needed to introduce the stock. When the clearance space appeared, the operator thrust the stock between the rolls. They gripped the stock, reduced it, and ejected it back to the operator. Because of the operator's position, forging rolls came to be called "back rolls".

About 1948, the machine was altered so that the rolls did not rotate continuously. Instead, they remain stationary in the "open" position, and are started when a "trip unit" is actuated by the stock as it enters the rolls. As an extra feature, these machines are usually provided with a foot pedal (see Fig. 4); this aids "jogging" during setup. The stop-motion feature means that only a small section of the rolls needs to be notched for entry of the stock. Thus, most of the circumference is available to work the metal. Rolls with smaller diameters can be used, and larger reductions per pass are possible with a smaller, less expensive machine.

Like rolling mills, forging rolls may contain a series of passes (successively shallower grooves), the number depending on the total reduction desired. Each time the rolls revolve to the "open" position, the stock is thrust back into the next pass. Either all or part of the stock can be reduced. If the latter, the reduced section may be anywhere along the bar.

These new stop-motion rolls have been widely used to rough out forging blanks intended for finishing in closed dies. Without this preliminary shaping, it is very difficult to forge a piece with both wide and narrow sections from a blank of uniform cross section in closed dies. Excessive flash and trim losses result. If the blank is roll forged first, the metal is disturbed in about the right proportions, and only a little longitudinal metal movement is needed to fill in the dies during final forging.

Advantages over other forging methods are:

1. Long, slender sections, with or without cross-sectional variations, can be made easily.

2. Shock and vibration of hammer forging are eliminated.

3. Roll dies last much longer than most forging dies.

4. Scrap loss in flash and trimmed ends is reduced.

5. Production rates of presses or hammers are greatly increased by preliminary roll forging.

Bigger, Better and Sounder Forgings

*By ERNEST E. THUM**

In an effort to improve the efficiency of large electrical generators, sizes and stresses have been increased to just about the capacity of the "standard" alloy steel forgings. This article outlines the metallurgical work being done to remove this very real limitation. The behavior of large notched disks, tested to destruction by spinning, simulates actual performance. New criteria have been found for toughness and ability to prevent cracks from starting and propagating. (Q26s; AY, 4-51)

DURING 1953 AND 1954, four massive forgings for large steam turbine-generator sets failed disastrously either in service or in test. The steel in three of these had the normal properties of a more-or-less standard analysis; 0.30% C, 2.75 Ni, 0.50 Mo, 0.10 V – the same as had been specified for literally hundreds of similar low-pressure rotors with long operating history free from trouble. The fourth was of a steel used for high-temperature service – 1% Cr, 1.25 Mo, 0.25 V. Two of them were operating at 3600 rpm. but two at the much more usual speed of 1800 rpm. Fractures in two of them occurred under normal operating conditions – the others during a routine check of a trip mechanism at less than 10% overspeed. All machines were of recent construction.

This sudden series of accidents led to intensive searches by the three American manufacturers of large electrical equipment and the four steelmakers who are able to produce the necessary heavy forgings. A progress report was presented late in 1955 to the Diamond Jubilee Meeting of the American Society of Mechanical Engineers (and summarized in *Metal Progress* for February 1956). Two failures were apparently due to high stress concentrations introduced by the design or by a repair, and the two others to defects in the steel. A study of the original ultrasonic inspection records suggested that the latter forgings were passed because the evidence was either misinterpreted or minimized.

This remarkable engineering session of the A.S.M.E. ended on a hopeful note. The ultrasonic records of 1500 medium-to-large forgings, as plotted in Fig. 1, indicated that the "Arizona" rotor which failed in the manufacturer's test pit would today have been subjected to supplementary tests. Conversely, any forging whose tests plot to the left of the "Inner Line" should be free from dangerous internal defects.

The Accident at Pittsburg, Calif.

Unfortunately, within six months – on March 18, 1956, to be exact, during routine test of the overspeed trip-out – a 22-month-old generator rotor at the Pittsburg station of Pacific Gas & Electric Co. near Oakland, Calif., split lengthwise into two half-cylinders (Fig. 2). The original forging (which was not center-bored) gave

*Editor-in-Chief, *Metal Progress*. The observations contained herein – his own – were principally inspired by a visit with Dolph G. Ebeling, head of metallurgy, and other members of the technical staff of the Large Steam Turbine-Generator Dept. of the General Electric Co., Schenectady, N. Y. Supplementary ideas were gathered at the First National Metals Engineering Conference of the A.S.M.E., held in Albany, N. Y., April 29 to May 1, 1959.

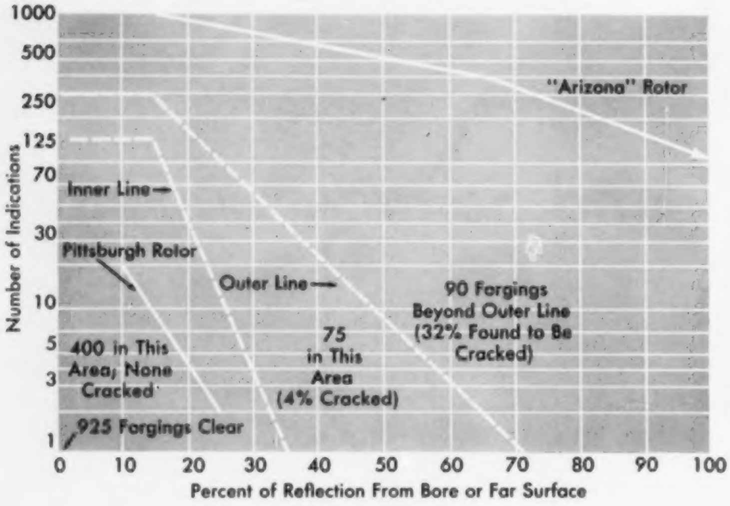


Fig. 1 – Total Ultrasonic Indications Were Plotted Against Their Size for 1500 Rotor Forgings; 925 of Them (62%) Were Clear of Definite Indications. Many suspicious indications were trepanned from the forgings or studied in rejects. As a result an area at lower left of the "Inner Line" indicates 400 forgings wherein no cracks could be found; 90 forgings plotted to right and above the "Outer Line" and one third of them were found to be cracked. The "Arizona" rotor which failed in a test pit before shipment had many large indications

test results well down toward the lower-left corner of Fig. 1 – in other words, it was rated "sound" by inspection methods that were in force in 1954.

Obviously there was some hitherto unrecognized feature of sonic testing. Why did it break when stressed one quarter to one third of its tensile strength?

A glib answer would be "It was a brittle forging", but that only shoves the inquiry back one notch to "What makes metal brittle?" Even when we know the answer to that one we would still have to ask "Why did not the most complete and skillful inspection by ultrasonic and other surveys give some warning?" A. W. Rankin, manager of turbine structural engineering of large steam turbines for General Electric Co., gave his answer in *Electrical World* for Dec. 2, 1957, paraphrased in the next paragraph:

The fracture originated in a segregated cluster of small manganese silicate inclusions very near the axis, 30 in. from one end (see Fig. 3). (Forgings for the generating machinery in the Pittsburg station were not center-bored or trepanned.) Fracture in this area was predominately intercrystalline; outside, it was transcrystalline ("shear type" fracture). Initial fracture originated and progressed slowly during service through a sizable area – 10 sq.in. – containing these inclusions and then catastrophically through solid metal in the rest of the forging. Under the existing stresses and temperature, the metal was unable to stop the crack from spreading at about the speed of sound.

But why did not the searching ultrasonic inspection give some indication of the existence of this dangerous accumulation of slag particles?

On original inspection of this forging which burst, this whole dangerous area had only two 25% indications, each corresponding to a questionable area roughly the size of a dime. Defects of this size were not considered serious. Subsequent theoretical analysis, checked by extensive microscopy, indicates that a glassy inclusion solidly embedded in metal will not give a detectable ultrasonic reflection (equal to at least 5% of the reflection from the bore or opposite surface) unless it is 0.010 in. thick or thicker. In service, the working stresses undoubtedly cracked many of the slaggy particles which existed but were not discovered ultrasonically. A tiny open crack is ten thousand times more easily detectable – the void needs be only 5×10^{-7} in. (0.000,000,5 in.) thick. The conclusion is that an area of tiny slaggy inclusions is not an observable discontinuity until it has been stressed enough to crack the inclusions or to form intercrystalline cracks in the metal growing from the slag particles.

Hence the logic of the suggestion of Westinghouse's Norman Mochel at the A.S.M.E. Diamond Jubilee Meeting, that large turbines should be periodically inspected in service. Indeed, the generator rotor of a sister unit was removed from the Pittsburg generating station and many of the small before-service pips showing a 5 to 10% reflection gave a 40% reflection. A 2.4-in. core was trepanned from one such position and when broken open showed a nearly continuous array of tiny manganese silicate inclusions in a 1.5×8-in. area and a fracture similar to the burst one (Fig. 3).

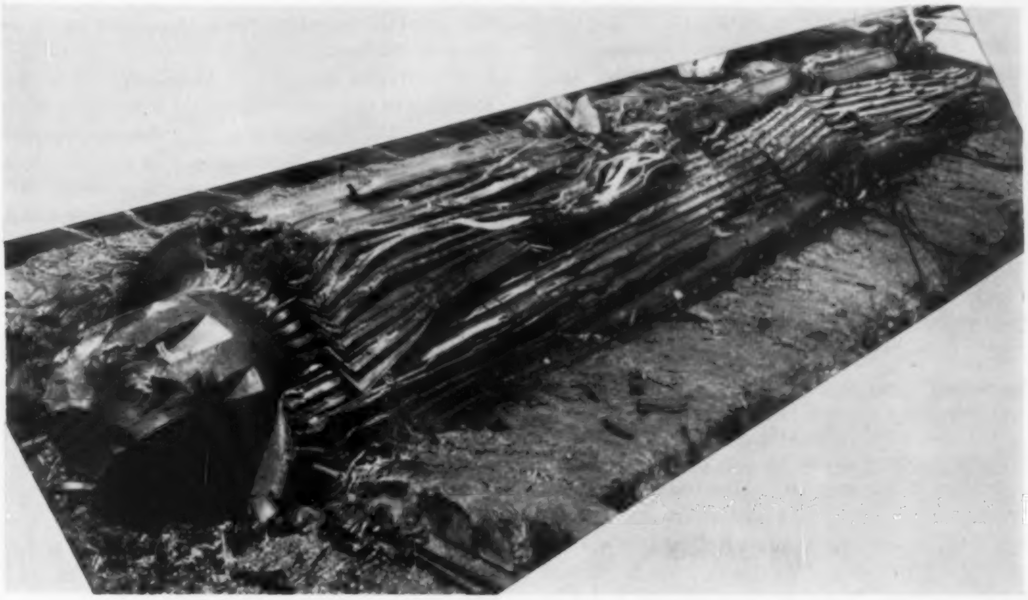


Fig. 2 – Pittsburg Rotor of 170,000-Kva. Generator Split Lengthwise Axially in Service

This is also the reason why it is desirable to re-inspect these large forgings after complete fabrication and acceptance testing at moderate overspeeds. Any potentially dangerous slag inclusions undiscovered in the rough forging should then have cracked, and the retest would then show much larger reflections at the location of ones previously thought innocuous.

Fig. 3 – Fracture Originated in 2 × 5-In. Area of "Woody" or Fibrous Appearance, Where Many Clusters of Glassy Inclusions Existed, Each One Too Small to Produce a Worrisome Ultrasonic Reflection

In the period between October 1956 and May 1959, about 135 generator rotors of General Electric manufacture have been reinspected by members of the turbine division; several of these showed larger ultrasonic indications than in the original tests; six of these have been bored to remove dangerous spots at the axis, and one has been removed from service. Furthermore, all the new rotors manufactured since the latter half of 1956, under the improved procedures to be described shortly, have been reinspected after factory overspeed tests and no changes in ultrasonics have been observed in any of them.

Improved Ultrasonic Techniques

A word should be said about the improved techniques devised by C. D. Moriarty and his associates in the nondestructive testing group at Schenectady. The rotors for both steam turbines and electric alternators are machined to correct outside diameters and a smooth bore trepanned out of the axis. It is then carefully inspected by optical, Magnaflux and die penetrant methods. Following this, it is mounted on a large lathe and slowly rotated while the ultrasonic test crystal is traversed slowly end to end in a tool holder; ultrasonic reflections are recorded continuously as to position and size (Fig. 4). This must be done when overhead cranes are immobilized. The complete outer surface is traversed in this manner; also a special fixture has been developed which fits the bore and surveys the entire body of the forging from that vantage ground.

This device, called a "boresonic unit", consists of two small ceramic crystals mounted very closely together in plexiglass. A small angular tilt to the crystals increases their sensitivity to flaws close to the surface.

A continual increase in knowledge as to the meaning of the sonic indications is resulting from a study of the actual cores trepanned from the center. Likewise the limitations of this excellent method of inspection are better appreciated. Already mentioned is its failure to record small glassy inclusions solidly embedded in metal. Another item is the inability to register defects just under a surface – to perhaps 0.10 in. It would seem that this can be circumvented by machining the forging that much oversize (and boring that much undersize), inspecting, and then removing a thin layer from the surface down to metal of unquestioned soundness.

The Steelmaking and Forging Problem

Before considering the metallurgical problems of "brittle" steel (or its converse, "tough" steel) in detail, it would be well to introduce the reader to the general requirements of large steam turbine-generators. By "large" one implies larger than 100,000-kw. output. Straight-line units such as sketched in Fig. 5 are being built to generate 275,000 kw.; steam enters the high-pressure casing at 2400 psi. and 1050° F.; the rotor speed is 3600 rpm.

Larger cross-compound units generating up to 500,000 kw. have the load split in two parts: The primary element is built like Fig. 5; the secondary element installed alongside is somewhat similar but its first stage receives the exhaust steam from the high-pressure unit, via a reheater. These larger units naturally require larger and

Fig. 4 – Piece of a Permanent Record of an Ultrasonic Test

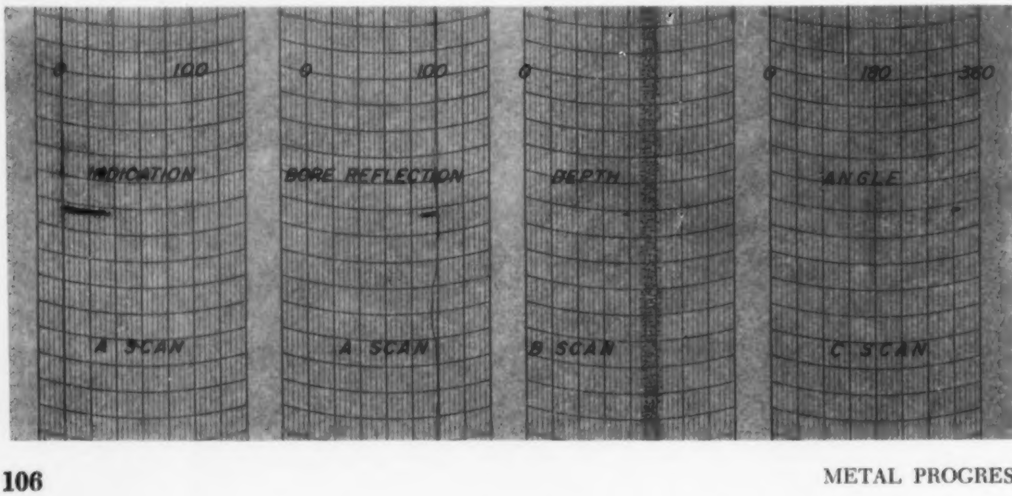
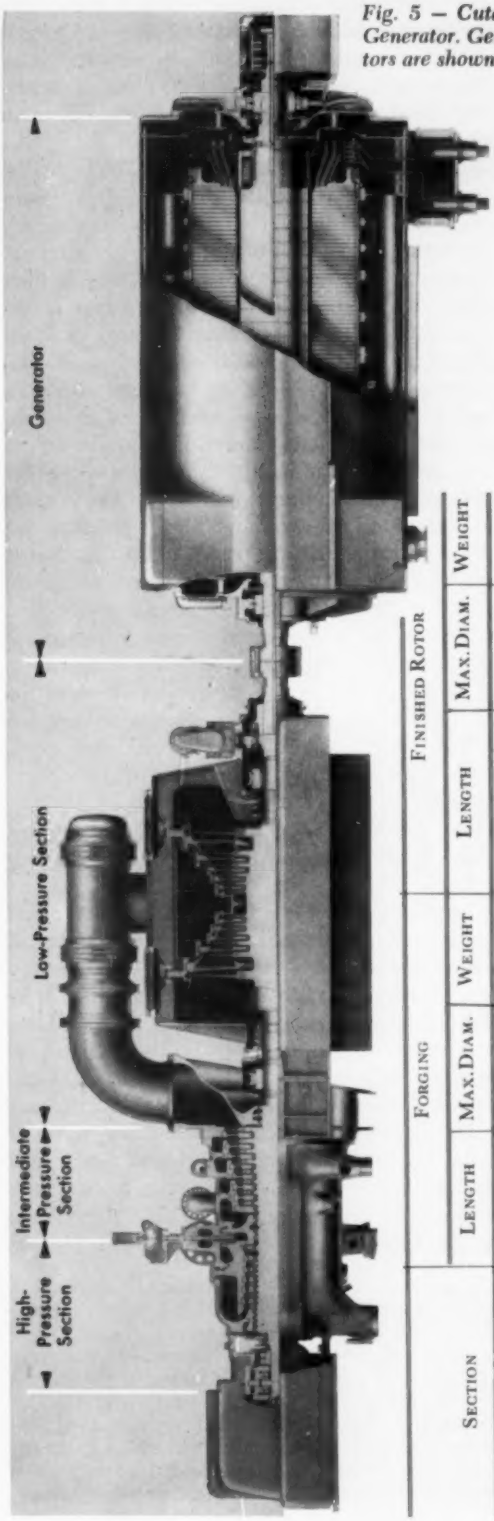


Fig. 5 — *Cutaway View of Modern Turbo-Generator. General dimensions of the four rotors are shown in the table below the diagram*



Section	Forging: Length	Forging: Max. Diam.	Forging: Weight	Finished Rotor: Length	Finished Rotor: Max. Diam.	Finished Rotor: Weight
High and intermediate-pressure	17 ft., ½ in.	3 ft., ½ in.	25,200 lb.	16 ft., 11 1/16 in.	3 ft., ¼ in.	20,600 lb.
Low-pressure	11 2¾	3 5⅛	35,525	11 2	3 4⅞	22,900
Generator	29 11	3 1⅝	74,500	29 10⅞	3 1½	53,700

stronger forgings. It might also be mentioned that the centrifugal stresses and operating temperatures in the large General Electric *generator* rotors have been reduced by a radical change in coil design. In the older conventional designs, the insulated conductors hammered down into the deep longitudinal slots have been solid copper bars; I^2r heat from currents generated during operation escapes by radiation through insulation and steel walls of the conductor slots into parallel passages carrying streams of hydrogen. In the new designs, the conductors are hollow copper bars and are cooled internally by hydrogen. Rotating mass and working temperature are both reduced — or conversely magnetic flux and total output of the generator is increased.

From the tabulation shown below Fig. 5, it will be seen that the largest of the forgings would require an ingot weighing over 100 tons. Any metallurgist at all acquainted with the ingot solidification mechanism will recognize immediately that certain things are inherent and inescapable, namely, "coring", or the intracrystalline segregation of soluble elements, the tendency of insoluble impurities to accumulate at grain boundaries and in the axial region, and the growth of large primary crystals. There is also the chance that a bridge might solidify across the upper part of the ingot and prevent adequate feeding of the mushy region below, thus permitting a pipe or porosity to form. Forging (which must be done in powerful presses) changes the chunky ingot into the required long round shape; it also is supposed to close small cavities and weld them shut; it also reduces the size of the primary grains. Final heat treatments are primarily designed to improve machinability and give an optimum combination of mechanical and magnetic properties.

Only four plants in the United States are equipped to do this kind of work, and it should be said at once that they have been cooperating in a joint effort with the three large electrical manufacturers to modify steelmaking, forging and heat treating practices in agreed-upon ways designed to improve quality. For example, the acid openhearth was formerly preferred by many metallurgists for the large forgings because it produced steel lower in hydrogen than could be made in basic furnaces, and hence less prone to those internal cracks called "flakes" and "fish-eyes". All four manufacturers can now vacuum-cast the largest ingots, and these are so much lower in hydrogen that the flake problem has been practically eliminated. (Maybe we should keep our fingers crossed, for the 0.5 ppm. of H_2 in vacuum cast metal is equal to 4% of the volume, measured at standard temperature and pressure.) All the large forging ingots are now of basic electric steel; double-slag refining can reduce the sulphur and phosphorus to the 0.015% level, and this has proportionately cut down the number of damaging inclusions. Oxide inclusions ("glasses") remain a problem – possibly also nitrogen and many tramp elements that are inevitably present in traces may prove to be deleterious.*

It should also be said that vacuum pouring has a definite effect on tensile *ductility* of "sound" metal (to many metallurgists this is a measure of toughness under service loads). For example, a heat of rotor steel was split and one half air-poured, the other half vacuum-poured. From then on the history was identical. Comparative reduction of area in standard tensile tests are as follows, where "aged" means heating to 200 to 300° F. to remove traces of hydrogen:

	Air-Poured	Vacuum-Poured
Aged test pieces	42% R.A.	55% R.A.
Unaged test pieces	25%	55%

Tougher Steel

While the above indicates the very considerable recent improvements in quality (freedom from porosity, flakes, thermal cracks) and in homogeneity (freedom from inclusions, segregates, and variations in grain structure), it doesn't say much about toughness, which is the ability of the material to resist the initiation and propagation of cracks. Here we run into the same dilemmas as faced the investigators of brittle ship steel. Again, here we can report much progress.

It is probably trite to say that a piece of metal breaks because it is asked to resist a stress larger than its ability to resist – larger than its ultimate strength. Also that discontinuities (defects) are dangerous because the stresses existing at their edges are much higher than the average across the entire piece; discontinuities are localized "stress-raisers". Also that if metal which "necks-down" – is plastic – in a standard 0.505-in. tensile test piece is rigidly restrained in all directions, plastic flow cannot occur under stress, and nonplastic or brittle fracture may be expected. (This indicates that *size* of the piece is important to load-carrying ability – either in test piece or manufactured part.) Also that brittle fracture occurs at catastrophic speed, so fast in fact that there is no time for normal plastic flow to relieve the concentrated stresses which cause the fracture to propagate. Also that *temperature* is to be added to the dangerous combination of circumstances in turbo-electric machinery. Finally, that brittle fractures are not confined to any single sphere of modern living; they have occurred in oil storage tanks, pipe lines, bridges, ships, gun tubes, aircraft fuselages and landing gear, missile fuel tanks, and turbine-generator rotors. (The list is not complete.)

Merely to state these factors is to indicate that books could be written and dozens of technical and theoretical sessions held and there would still be no simple answer to the question "Why did that rotor break?" – or, more pertinent, "How can we avoid future trouble?" The second portion of this article, to be published next month, can do no more than sketch briefly the work being done at Schenectady by a large group of keen engineers in exceedingly well-equipped quarters under the general direction of C. Schabtach, manager of engineering for the large steam turbine-generator department.

*The mind naturally turns to the possibilities of the consumable-electrode method. It might work out this way: A basic electric heat of proper size and composition would be continuously cast into a 12-in. round billet (electrode) 650 ft. long. It would be uniform in composition, end to end. This would be remelted in high vacuum by electric current or electron beam into a water cooled copper mold fairly close to the necessary rough-machined shape. It would be very low in oxygen, hydrogen (probably nitrogen), volatile metals and nonmetals, and hence free from macroscopic inclusions. Ultrasonic vibration of the solidifying metal would produce small grain size, as cast. There would be no edge-to-center or end-to-end segregation. Ideally there would be no porosity. Nothing much more than a stress-relieving anneal would be needed in the way of heat treatment. Just cast it, anneal it, machine it, inspect it, and use it! No need for center bore to remove axial impurities and defects; there wouldn't be any.

New Metallographic Techniques

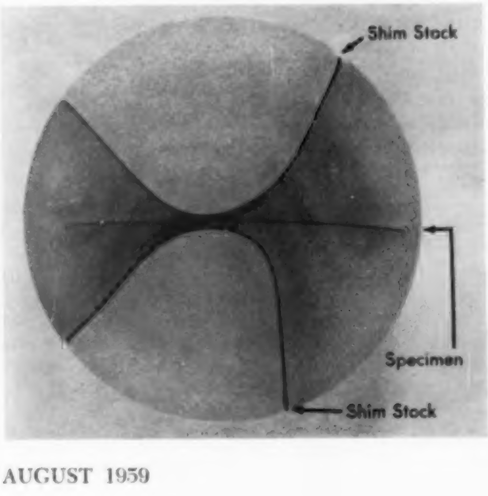
Preparing Foil for Micro-Examination

*By DOROTHY J. RAHN**

The problem was to prepare cross sections of foil less than 1/16 in. thick for metallographic study. The procedure is based on a mounting medium which cures at room temperature and on careful control of polishing. (M20; 4-56)

IT WAS A RARE INSTANCE in the past when a metallographer was called on to study the microstructure of a specimen less than 1/16 in. thick. True, needle wire and surgical instrument stock of small diameter have been examined metallographically. However, these were usually prepared to present a face longitudinal to the direction of rolling or extrusion. Precise grinding to obtain a field at the center of the specimen presented the greatest problem. If the study of a transverse section was desired, the specimen usually was stiff enough to permit it to be mounted on end in a thermal-setting resin.

Fig. 1 – An Enlargement of the Polished Face of a Mounted Foil Sample. The two U-shaped members serve as supports while the mounting material is being poured.



The widespread use of foil in packaging, in transducers, in automobiles (as shim stock), in printed circuits, and in nuclear reactors has brought new challenges to the metallographer. He is asked for a microstructural study of foils before and after exposure to corrosive atmospheres. Frequently, these foils are permanently deformed under stress in a corrosive environment so that the difficulty of mounting and polishing is increased. This article gives procedures which we have developed to prepare foils ½ to 3 mils thick for microstructural examination.

Several types of steel foil were chosen for study because of their different hardness characteristics: (*a*) A.I.S.I. Type 304, as received from the mill; (*b*) Type 304, heat sensitized after exposure to corrosive atmosphere; (*c*) Type 304, chromium plated; (*d*) a section of feeler gage stock made from carbon toolsteel.

Mounting Poses Problems

When lucite, Plexiglass or bakelite is employed, heat and pressure are necessary to cure the mounting material. The pressure required during the curing cycle is sufficient to topple the foil standing on end. Consequently, mounting resins which cure without the application of heat were investigated. The most satisfactory one for

*Chief Metallographer, Atomic Power Dept., Westinghouse Electric Corp., Pittsburgh.

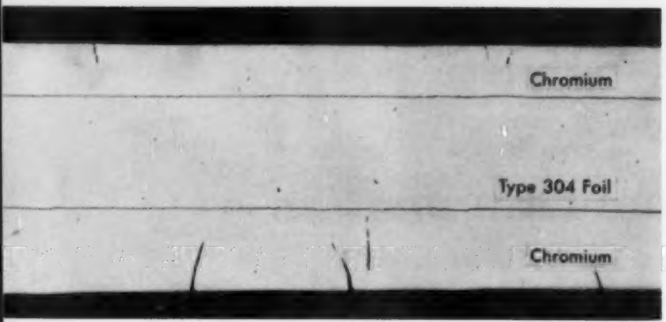


Fig. 2 – Chromium-Plated A.I.S.I. Type 304 Foil. Unetched; 250 ×

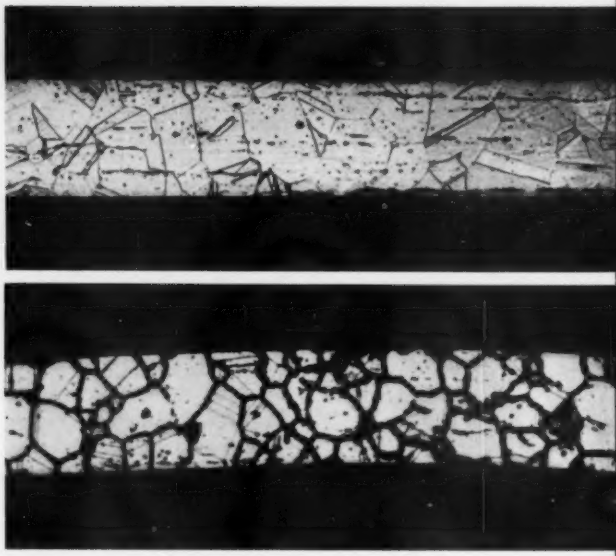


Fig. 3 – A.I.S.I. Type 304 Foil (3 Mils Thick). Top, in the as-received condition; bottom, heat treated to induce sensitization. Electrolytically etched in chromic acid; 250 ×

our use is a commercial product* which requires no heat, pressure, or forced cooling during curing. This product shrinks negligibly and the aged mounting material remains in intimate contact with the specimen – important where edge preservation is required. The mounting material is a powdered resin, resembling lucite, to which a catalyst is added when the specimen is ready to be mounted. Curing time is about 20 min. Apparatus required for this type of mounting includes flat plate, a retaining ring, a beaker and a stirrer to mix the resin and the catalyst used for mounting.

Figure 1 illustrates the polished face of a mounted foil specimen. The horizontal member is the foil sample. The two curved members are shim stock bent in such a fashion as to support the foil while the resin is poured.

Polishing Requires Special Care

Extensive effort was made to polish foils electrolytically. We found that the mounting material reacts with many of the electrolytes and that edges of the specimens are preferentially removed. Automatic grinding and polishing also rounded the edges. The more conventional hand polishing was finally found to be successful. This is no assignment for the novice, but with practice any operator who can prepare conventional specimens well should be able to handle the job.

Success depends on removing material at a uniformly decreasing rate by controlling the pressure applied to the specimen and the quality of the abrasive used. When the pressure is abruptly increased, the face being prepared may become cold worked to a nonuniform depth. During subsequent polishing, all the cold worked material may not be removed. Abrasives of nonuniform grit, or grit with worn, rounded edges, alter the rate at which material is removed. Hence, cutting disks and polishing powders employed during hand polishing and grinding must be of excellent quality and must be changed frequently.

Polishing time is another important variable. Relief polishing at the specimen-mount interface and between materials of different hardness which comprise the specimen is minimized if the grinding and polishing steps are performed just

*Kold-Mount – manufactured by the Vernon Benshoff Co. in Pittsburgh.

Table I – General Procedure for Polishing Foil Cross Sections

Step	Pressure	Abrasive Type	Abrasive Grit	Lubricant	Time (Approx.)	Wheel Covering
1	Heavy	SiC	120	Water	3 min.	Paper disk
2		SiC	180	Water	3	Paper disk
3		SiC	240	Water	3	Paper disk
4	to	SiC	320	Water	3	Paper disk
5		SiC	400	Water	3	Paper disk
6		SiC	600	Water	3	Paper disk
7		Diamond	6μ	Lapping oil	6	Nylon
8	Light	Al_2O_3	0.1μ	Distilled water	3	Nylon

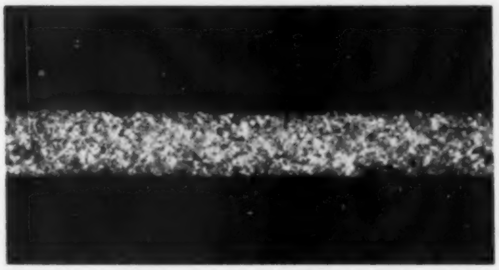


Fig. 4 — Feeler Gage Stock Made From Carbon Toolsteel (1.5 Mils Thick). Nital etch; 250 ×

long enough to remove previous scratches and if hard napless cloths are used on all polishing wheels.

Manual Pressure Is Important

The operator preparing a foil specimen should bear in mind that success depends on using an initially heavy, then evenly decreasing, pressure. Heavy pressures at the beginning of the grinding operation do not contribute to a misleading structure on the finished sample if lubrication is adequate and if the rate of material removed is diminished gradually and uniformly so that all cold worked metal is taken off.

Techniques are given in Table I for grinding and polishing foil specimens of stainless and carbon steels, copper, and uranium alloys.

Photomicrographs of specimens prepared by the method given in Table I are shown in Fig. 2, 3, and 4. Figure 2 is a photomicrograph of a chromium-plated Type 304 foil. Hardness values of the steel base metal and the chromium plate are Rockwell B-88 and C-66, respectively. Careful control of the cutting rate and polishing time resulted in a flat specimen without edge rounding. In Fig. 3, Type 304 steel is in the as-received condition at top while below the material had received a sensitization heat treatment at 1300° F. followed by furnace cooling. It was difficult to preserve edge zones on the latter sample when conventional mounting and polishing methods were used. A feeler gage of carbon toolsteel, 1.5 mils thick, is shown in Fig. 4. Despite the extreme thinness of the stock, its edges are not rounded.

Mounting Thin Tungsten Wire and Sheet

*By U. E. WOLFF and L. B. FRADETTE**

Fusing tungsten wire in glass prior to mounting improves the flatness of transverse and longitudinal samples for metallographic study. (M20; W, 4-53, 4-61)

RETENTION OF SHARP EDGES during preparation of small samples for metallographic examination is difficult, especially if the material is as hard as tungsten. We have developed methods for effectively handling this problem in our laboratory.

Wire Is Fused in Glass

Since tungsten does not undergo structural changes below 1800° F., thin wire specimens, up to about 0.015 in., can be fused in thick-walled Pyrex capillary tubing. The coefficients of expansion of tungsten and Pyrex glass match sufficiently to produce tight seals. The capillary with the wire inserted in it is held in a flame at an angle. Fusion is started at the lower end and is continued slowly upward to permit the escape of all air. The end containing the wire is cut or broken off and mounted in bakelite.

As an alternative procedure for longitudinal sections, the soft glass is flattened with a spatula on a rough surface such as an asbestos wire screen. This has the advantage of reducing the depth to be ground off and of giving the mounting plastic a better grip on the glass.

If electrolytic polishing is desired, the wire-

*Refractory Metals Laboratory, Lamp Metals and Components Dept., General Electric Co., Cleveland.

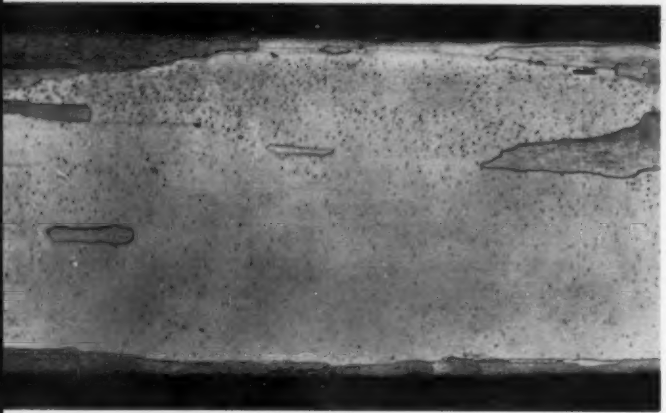


Fig. 1 – Longitudinal Section of an Annealed Tungsten Wire 10 Mils Thick. Electrolytically polished and etched with copper-ammonium sulphate. 250 ×

Fig. 2 – Longitudinal Section of an Annealed Tungsten Wire 10 Mils Thick. Etch-polished and etched with copper-ammonium sulphate. 250 ×

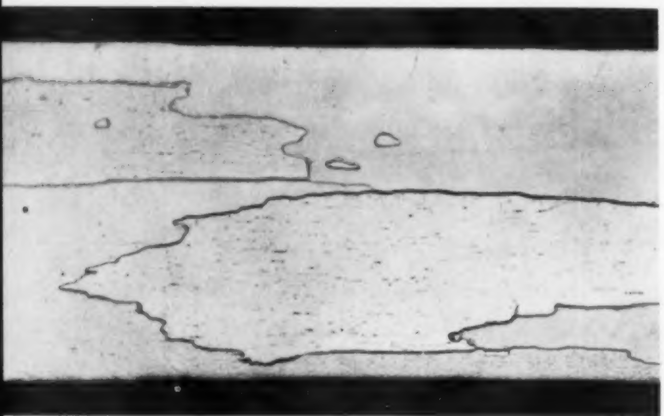


Fig. 3 – Transverse Section of an Annealed Tungsten Single Crystal. Etch-polished and etched with copper-ammonium sulphate. 250 ×

glass assembly should be made so that one end of the wire protrudes from the glass into the mounting medium (we use a conductive resin*).

Mounting and Polishing Numerous Samples

To prepare a large number of wire samples, a different method is used. Up to 5 or 6 samples can be mounted in a single 1-in. mount after suitable identification of the individual wires. A simple way to do this is to mark each of the wires with a colored grease pencil before mounting them in a transparent resin. For electrolytic polishing, the cell circuit is established through the specimens by grinding a flat vertical face on the side of the mount so that all the wire ends are exposed. Each specimen can be polished individually by touching its exposed end with a copper wire from the positive terminal of the power supply. If simultaneous polishing is desired, the mount is placed in a metal clamp which connects all the wire samples electrically. Provisions must be made during polishing to avoid contact of the clamp and copper wire with the electrolyte.

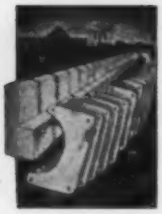
Tungsten is polished electrolytically for 10 to 20 sec. in a 2% sodium hydroxide solution at 25 v. If longer polishing times are required, the samples tend to become overheated and etched. This can be avoided by interrupting the polishing cycle every 20 sec. and cooling the samples with the agitated electrolyte. Figure 1 is a photomicrograph of a tungsten wire which has been electrolytically polished.

An alternative to electrolytic polishing which prevents edge rounding has been developed by Millner and Sass†. The sample is alternatively polished with a gamma-alumina suspension, then a solution of 1 g. copper sulphate in 5 to 10 cc. water, 20 cc. concentrated ammonium hydroxide, and enough gamma-alumina polishing suspension to make 1000 cc. Etching is done by dipping the sample in a solution of 10 g. copper sulphate (in 40 cc. water) and 20 cc. concentrated ammonium hydroxide. Tungsten samples prepared by this technique are shown in Fig. 2 and 3.

With appropriate variations, these techniques are applicable to sheet material and, of course, are not restricted to tungsten.

*Conductive Mounting Resin No. 2 – sold by Uddeholm Co. of America, Inc., New York.

†"A New Method for Polishing and Etching of Metallographic Specimens of Tungsten and Molybdenum Metal", by T. Millner and L. Sass, *Aluminium* (Budapest), Vol. 5, 1953, p. 214-215; Brutcher Translation No. 3281.



Short Runs

Repairing Steel Castings by Submerged Arc Welding

Defects in heavy carbon and alloy steel castings are repaired by submerged arc welding at the Penn Electric Steel Casting Co., Hamburg, Pa. By varying the flux composition slightly, deposited metal can be adjusted to match the composition of the casting, whether mild steel or alloy. The process uses special alloy fluxes (furnished by Lincoln Electric Co., Cleveland) which contain carbon and ferro-alloys of manganese, silicon, chromium and molybdenum in suitable proportion to give a deposit equivalent to the base metal.

Voids in the large slide shoe (Fig. 1) of low-carbon steel are being filled by the Lincoln "Squirt" welding technique. A mild steel wire 5/64 in. in diameter is fed into the gun while flux is deposited continuously over the arc from the cone hopper. The deposit is applied with no preheat at about 400 amp. d-c. and 34 volts.

A suction hose removes excess flux. The thin slag deposited over the weld metal is flaked off easily with an air chisel when additional passes are required to fill the void completely. Where several passes are necessary, the slag is sometimes left on the deposit a little longer than usual to promote slow cooling and avoid excessive hardness. Succeeding passes also have an annealing effect on the metal beneath them.

Alloy castings of A.S.T.M. classifications WC-3, WC-6 and WC-9 can be repaired similarly. On these, the same 5/64-in. filler is used. On alloy jobs, the castings are preheated 300 to 600° F. and welded at 375 to 400 amp. d-c. and 34 v.

Fig. 1 – Surface Defects in a Slide-Shoe Casting Are Chipped Out and Filled by Semi-Automatic Submerged Arc Welding

Correspondence

Midsummer Madness

After glancing at the first two lines of the article on p. 72 of the July issue of *Metal Progress* ("Hydrogen in Heavy Forgings", by J. E. Steiner), our readers may have wondered if the summer heat had addled their wits. It hadn't. By some typographical legerdemain at our printer's plant, the first line of Mr. Steiner's article was replaced by the first line of one of the following articles – with the resultant metallurgical gibberish. The first sentence of the article *should* have read: "Forgers have known for years that hydrogen plays an important role in thermal flaking."

A New Look for Metallurgists

CLEVELAND, OHIO

In our efforts to promote the metallurgical profession, I don't think we should overlook the contribution of metallurgist James Astrue. For weeks, Lt. Astrue held sway on a daytime television quiz program called "Tic Tac Dough", exhibiting knowledge on a whole gamut of subjects. Now when my wife visits with the bridge club set and states that her husband is a metallurgist, she is no longer confronted with pictures of a psychiatrist (mentallurgist"), a bearded man holding test tubes, or a blacksmith with hammer and tongs; instead a picture of a smart, personable young man like Jim Astrue is brought to view.

RICHARD J. QUIGG
Research Metallurgist
Thompson Ramo Wooldridge Inc.

Vickers-Knoop Hardness Conversion Discussed

COLUMBUS, OHIO

In the article "Vickers-Knoop Hardness Conversion", by Lloyd Emond, which appeared in *Metal Progress*, September 1958, p. 97, I note a statement which has caused considerable confusion for many years. This statement indicates that the elastic recovery of the Knoop indentation (but not the Vickers) is larger at light loads than at heavy loads. Since recovery is a dimensionless quantity equal to the change in length per unit length upon removal of the load, it is difficult to see how such a quantity could vary when the stress, as measured by the hardness number, remains nearly constant. Properly speaking, the recovery of a hardness indentation upon removal of the load is a function only of the modulus of the material being tested and of the stress applied (not the load). Since the hardness number obtained is proportional to the stress applied by a pyramidal indenter, the hardness number can be considered a measure of that stress. It follows that the recovery of a pyramidal hardness indentation is a function of the hardness of the material, not of any external factors such as the size of the machine used to make the test.

By implication, the increase in Knoop hardness at low loads noted by Mr. Emond and other users of the Tukon hardness machine is caused by the inability to locate the ends of the indentation and by other systematic errors such as optical resolution of the microsope, and inertia and friction in the loading system. The Tukon machine can operate over a tremendous range of loads; however, bearing surfaces and lever arms designed to support 50,000 g. become subject to systematic errors when engineers attempt to test with 10-g. loads.

The Tukon machine and other precision instruments* have shown that the square-based Vickers pyramid indenter is independent of the load applied. It seems quite likely that the Knoop pyramid indenter will show the same independence when used in a machine designed to respond with precision to 10-g. loads.

WALSTON CHUBB
Battelle Memorial Institute

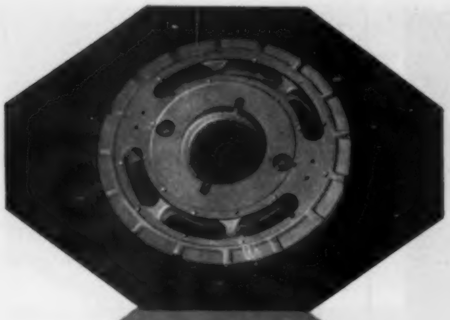
AUTHOR'S REPLY – The statement to which Mr. Chubb refers was not meant to indicate that elastic recovery itself is larger at light loads than at heavy loads, but rather that recovery, being independent of load, is a greater percentage of the indentation length at light loads than at heavy loads. Thus a greater error is introduced when using light indenter loads.

Investigations by Tate† and Bergsman‡ have shown that, since

*"A New Design of Microhardness Tester and Some Factors Affecting the Diamond Pyramid Hardness Number at Light Loads", by R. F. Campbell, Q. Henderson and M. R. Donleavy, *Transactions*, American Society for Metals, Vol. 40, 1948, p. 954.

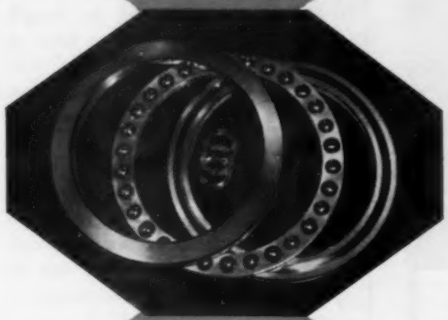
†"A Comparison of Microhardness Indentation Tests", by Douglas R. Tate, *Transactions*, American Society for Metals, Vol. 35, 1945, p. 374.

‡"Some Recent Observations in Microhardness Testing", by E. Borje Bergsman, *Bulletin*, American Society for Testing Materials, Technical Paper No. 176, September 1951, p. 37.



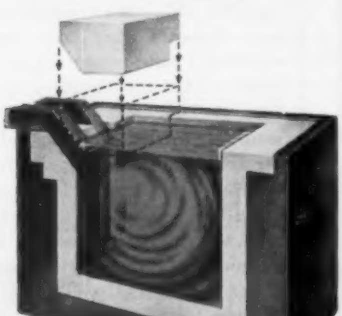
Martempering tamed this heat treater's "nightmare"!

This Vasco B. B. steel valve plate is 11⅜" in diameter and varies in section from ½" to 1⅝". Ajax austenitizing and martempering followed by air cool and draw hardens it to Rc 63-64 on the lighter sections and to Rc 60-64 on the 1⅝" section — without cracking, distortion or surface defects.



Assuring bearing race hardness . . . without distortion.

Freedom from distortion and extreme surface hardness are essential to these 52100 steel bearing races. Ajax austenitizing with Ajax cataract quenching plus air cool and draw supply these characteristics in full measure — on a fast production basis.



Hundreds of pounds of work an hour . . . from a furnace no larger than your desk!

When it comes to hardening high alloy steels . . .

THERE'S NO MATCH FOR SALT BATH SPEED, FREEDOM FROM DISTORTION AND UNIFORMITY

In hundreds of applications throughout industry, Ajax neutral hardening salt baths are providing far and away the fastest, most economical means of heat treating valuable high alloy steel materials.

- Furnace productive capacity is several times that of other methods because of safe, yet faster heating.
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- Built-in surface protection guards against scaling, decarb and pitting.
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AJAX HULTGREN

SALT BATH FURNACES

Internally heated electric and gas-fired types

Correspondence . . .

the form of the Knoop impression is independent of indentation load, the stress distribution around the corners of the unrecovered impression should be the same for any load. Therefor, the elastic recovery, determined by the stress distribution, should also be independent of indentation load.

Thus for a given material, a constant correction length could be applied to the measured Knoop indentation lengths for different loads, implying that elastic recovery in the long dimension must be constant for a given material.

Identical conditions were also considered to exist for Vickers indentations, but because of the larger angle between the edge of the Vickers indenter and the surface of the specimen, the change in length would only be about one fifth as great.

While elastic recovery had an effect on Knoop hardness, especially at low loads, its effect was less than that of the visual and other systematic errors mentioned by Mr. Chubb. It seems preferable to report Knoop indentation numbers without correcting for elastic recovery, and to include the indenting load used.

LLOYD EMOND

Further Comments on Vickers-Knoop Hardness Conversion

BREMEN, GERMANY

In the article on "Vickers-Knoop Hardness Conversion", the accompanying data sheet seems to indicate that the deviation from the nearly 1:1 ratio between Knoop and Vickers hardness numbers valid for 500 g. increases with decreasing load. However, Mr. Emond compared Knoop 500, 15 g., with Vickers hardness numbers gained by using 10-kg. loads. This procedure may unfortunately lead to serious misunderstanding.

Because of the well-known relationship between load and hardness for loads smaller than some hundred grams, tests to determine the relationships between Vickers diamond pyramid and Knoop diamond rhom-

Correspondence . . .

bus hardness numbers should always use the same load for both hardness measuring systems. Therefore, the data sheet does not show the real relationship between Vickers and Knoop, but the relationship between small and high loads.

The necessity for reliable conversion data between Vickers and Knoop was realized at the Institut für Härterei-Technik, too. In our series of tests, indentical loads were used for both measuring systems. The results seem to confirm a ratio close to 1:1 for the small loads. They show that the deviations from this ratio are so small that they can be neglected for all practical purposes. Case depth determinations using the same critical hardness numbers (630, 600, 550, 500) result in values differing by no more than 0.01 mm. with shallow cases and no more than 0.07 mm. with cases about 1.2 mm. and a very shallow gradient.

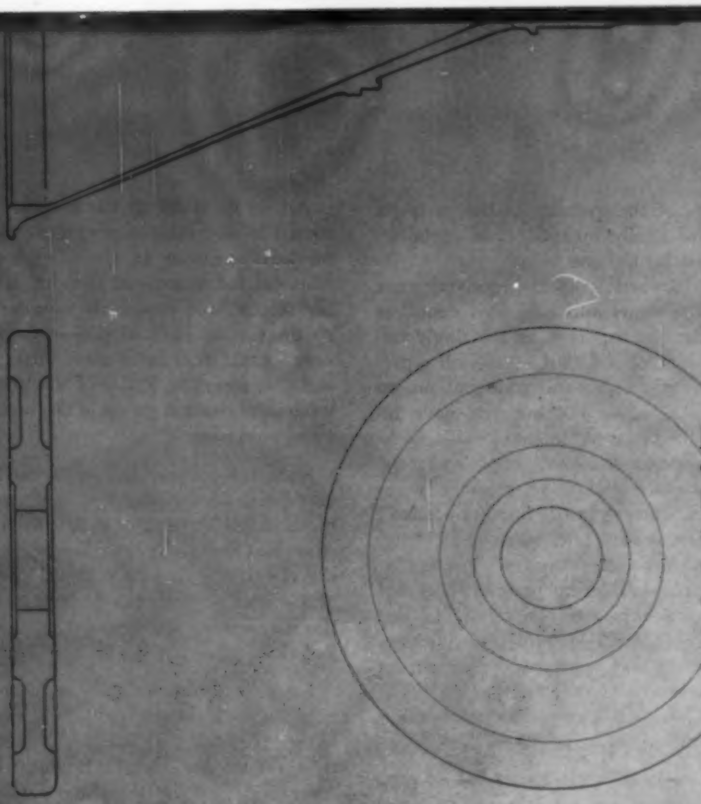
OTTO SCHAABER
Institut für Härterei-Technik

AUTHOR'S REPLY — In replying to Dr. Schaaber's comments, the purpose of our conversion tests should be explained. Because of the lack of published data on Knoop hardness relationship to other hardness values when using light Knoop indenter loads, it seemed desirable to determine this relationship. The Vickers hardness scale was chosen for its close relationship to Knoop hardness and its greater range of hardness values.

Since we used a 10-kg. load most frequently on the Vickers machine, we decided to compare the Knoop hardness obtained at light loads to the Vickers hardness numbers using the 10-kg. load. After establishing this relationship, Knoop hardness numbers for light loads can be compared to the more familiar diamond pyramid hardness scale.

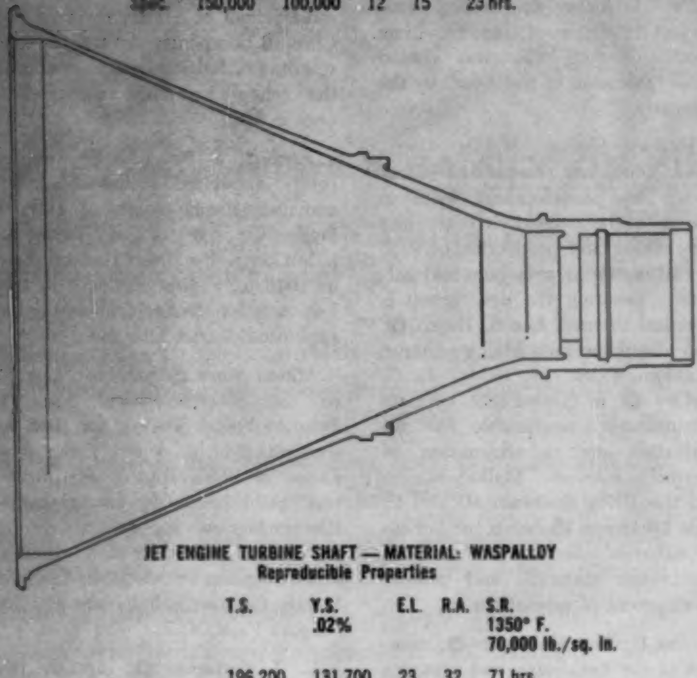
Alco Products, Inc., carried out a similar investigation, comparing Knoop hardness at various loads to Vickers, Rockwell C and Rockwell superficial scales. The comparison of Vickers, using a 10-kg. load, was plotted from their data and shows a similar, though somewhat greater, increase in hardness at light Knoop indenter loads.

LLOYD EMOND



JET ENGINE TURBINE DISC — MATERIAL: INCO 901

	T.S.	Y.S. .2%	E.L.	R.A.	S.R. 1200° F. 80,000 lb./sq. in.
	175,000	128,000	20	23	225 hrs.
Spec.	150,000	100,000	12	15	23 hrs.



JET ENGINE TURBINE SHAFT — MATERIAL: WASPALLOY
Reproducible Properties

	T.S.	Y.S. .02%	E.L.	R.A.	S.R. 1350° F. 70,000 lb./sq. in.
	196,200	131,700	23	32	71 hrs.
Spec.	160,000	90,000	15	18	23 hrs.

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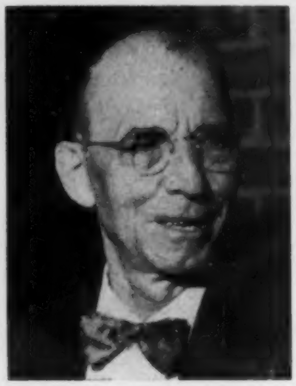
Personal Mention



Howard Scott

When HOWARD SCOTT ⊕ retired after 33 years with Westinghouse Electric Corp., his associates joined together for a testimonial dinner to honor a good friend and metallurgist, well known for his achievements in his field. Some entertaining excerpts from one of the highlights of this evening appear in this month's Light Metallurgy section on p. 85.

Born in Rockville, Md., Scott enrolled in George Washington University in September of 1912 and – a month later – took on an additional job at the National Bureau of Standards as a laboratory apprentice for an assistant physicist. Receiving his bachelor of arts' degree six years later, he continued to work at the Bureau, doing research on duralumin and other aluminum alloys and acquiring a long-lasting interest in solution treatment and aging.

In September 1920 he turned to teaching and a post as instructor of metallurgy at Harvard University, returning to the Bureau a year later as a physicist. Five years later he decided to make his way in industry and joined Westinghouse Electric Corp. Research Laboratories, rising to section manager in 1930, manager of the metallurgical department and finally in 1954 chief metallurgist for the company.

Howard Scott has received some 33 patents and delivered countless scientific papers on an amazingly varied number of subjects – all representing important contributions to metallurgy. His interests have included heat treatment of steels, high-temperature alloys, glass-metal seals, bimetals, and more recently problems such as brittle fracture connected with large rotor forgings for steam turbines and generators.

These interests extend into his technical memberships; he is known for his A.S.T.M. work on hardness testing and prepared the section on that subject in the first ⊕ Handbook. In addition he was chairman of the Pittsburgh Chapter ⊕ in 1938.

Boyd E. Cass ⊕ has been promoted to general sales manager of Foote Mineral Co., Philadelphia. Associated with the company since 1945, he formerly served as manager of metallurgical sales.

Paul J. Aicher ⊕, Chicago area district manager of the Beryllium Corp., Reading, Pa., was chosen 1959 "Salesman of the Year" by the company.

Mallory-Sharon Metals Corp., Niles, Ohio, has reorganized its research and development team in line with the company's entry into the refining and production of such special metals as zirconium and hafnium. Heading the new group is technical director **Lee S. Busch** ⊕, who joined the then Mallory-Sharon Titanium Corp. in 1954. **L. G. McCoy** ⊕ is government contract administrator, responsible for coordination and administration of contracts between Mallory-Sharon and the U. S. Government, and **C. Dale Dickinson** ⊕ heads fundamental research. **Stanley Abkowitz** ⊕ directs the materials and process development of new alloys.

John Herbert Hollomon ⊕, manager of the metallurgy and ceramics research department at the General Electric Research Laboratory in Schenectady, N. Y., has been elected a Fellow of the American Academy of Arts and Sciences.

Arthur B. Shuck ⊕ has been promoted to the rank of senior metallurgical engineer at the Argonne National Laboratory in Lemont, Ill. Mr. Shuck, who joined the metallurgy division in 1949, is project engineer for the fuel fabrication facility and also serves as leader of the plutonium fabrication group in the metallurgy division.

Kurt S. Sealander ⊕ was recently appointed sales manager of the Alabama Metallurgical Corp., Selma, Ala. He was formerly affiliated with the Howard Foundry Co. and Hills-McCanna Co., both in Chicago, and the magnesium division of Alcoa in Buffalo.

Louis A. Carapella ⊕, vice-president of Sylvania-Corning Nuclear Corp., Hicksville, L. I., N. Y., was the recipient of the Distinguished Alumni Award at the June commencement exercises of Michigan State University, the first such award made by the University.

Kenneth C. Russell ⊕, a metallurgical engineering senior at the Colorado School of Mines, received the Clark B. Carpenter Award for outstanding scholastic achievement at the school's commencement exercises in May.

Frederic S. Boericke ⊕ was recently appointed technical service manager, Pacific coast, of Haynes Stellite Co., a division of Union Carbide Corp. He joined the company in 1946 as a sales engineer in the Los Angeles district and was later appointed district sales manager.

Milton Stern ⊕ has been awarded the Electrochemical Society's Prize to Young Authors for 1958 in recognition of his paper "The Mechanism of Passivating-Type Inhibitors", published in the Journal of the Electrochemical Society. Dr. Stern is technical supervisor of the metals research group at the Union Carbide Metals Co. research laboratories in Niagara Falls, N. Y.

C. T. Patterson ⊕, recently retired chief metallurgist for Solvay Div., Allied Chemical Corp., Syracuse, N. Y., has been appointed consulting metallurgist at the U. S. Bureau of Mines, Albany, Ore.

Personals . . .

W. A. Johnson, formerly associate director, staff research and development, metallurgy and chemistry, for Thompson Products Div. of Thompson Ramo Wooldridge, Inc., has been promoted to the position of manager of metallurgy and chemistry of the Tapco Group of the company.

Gordon Meldrum, past chairman of the Canton-Massillon Chapter, was recently appointed assistant chief metallurgist of Republic Steel Corp.'s central alloy district. Mr. Meldrum, who has been in metallurgical work in the district since 1936, last served as alloy metallurgist for the company.

F. J. Lockhart has been named vice-president, sales, North American division, for Atlas Steels Ltd., Welland, Ont. His former position was vice-president, Canadian sales.

William T. Strickland, for the past six years sales engineer in the Detroit office of Timken Roller Bearing Co., Canton, Ohio, has been appointed district sales manager of the New England area for the company's steel and tube division. His former position in Detroit will be filled by **Bruce R. Wise**, a sales engineer at the Cincinnati office.

Herbert V. Ross has resigned as superintendent of the Central Shops, Argonne National Laboratory's facility in Lemont, Ill., for the engineering design and construction of special equipment used in nuclear energy research, to accept a position with Combustion Engineering Corp., New York.

Malcolm F. Judkins, formerly director of new product development for Firth Sterling, Inc., Pittsburgh, has been appointed technical director, commercial production engineering, for Sylvania-Corning Nuclear Corp. with headquarters at the company's Hicksville, L. I., N. Y., plant.

Carl F. Joseph, technical director of the central foundry division of General Motors Corp., Saginaw, Mich., received the McCrea Medal, the highest honor offered by the malleable iron industry, at the Malleable Founders' Society annual meeting in Hot Springs, Va.

Personals . . .

Augustus B. Kinzel, vice-president, research, of the Union Carbide Corp., New York, has been awarded the Stevens Institute of Technology Powder Metallurgy Medal for outstanding achievement in the field of powder metals.

Emo D. Porro was recently appointed vice-president of Broadview Research Corp., Burlingame, Calif. Mr. Porro was formerly executive vice-president and general manager of Thermo Materials, Inc.

Bani R. Banerjee, formerly senior project physicist in the research and development department of Standard Oil Co. of Indiana, is now supervisor of the applied physics section of Crucible Steel Co. of America's central research laboratory in Pittsburgh.

Arthur Lawler, Jr., has been assigned to the sales staff of Vanadium-Alloys Steel Co., with headquarters in the New York district office. Mr. Lawler, membership chairman of the Worcester Chapter, will sell and service tool and special steel products in southern Connecticut.

George W. Hallock has retired from his position as senior engineer in powder metallurgy, specializing in tungsten, molybdenum and their alloys, for the chemical-metallurgical division of Sylvania Electric Co., Towanda, Pa., to set up a consulting service in Dunedin, Fla.

Ralph H. Herzler, Jr., has been named product manager, aluminum, for Chase Brass & Copper Co., a subsidiary of Kennecott Copper Corp., Waterbury, Conn. He joined the Chase sales organization in June 1958 as aluminum specialist, covering midwestern sales districts from the Chicago office.

Harry P. Kling has joined the Martin Co. nuclear division in Baltimore, Md., as manager of the nuclear components department, where he will direct all research, development and production on fuel elements, control rods and other components used in reactors and isotopic power units. He was formerly associated with Sylvania Electric Products, Inc., and Sylvania-Corning Nuclear Corp. for ten years.

AMCHEM Information Bulletin

A REVIEW OF PHOSPHATE COATINGS

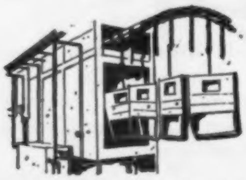
Specified for the Protection of Metal Surfaces

By HUGH GEHMAN, Assistant Manager, Product Development Dept., AMCHEM PRODUCTS, INC.

Phosphate coatings are protective inorganic finishes that actually change the chemical nature of metal surfaces. The metal reacts with the applied phosphate solution to form a nonmetallic, crystalline coating which serves to:

- Improve paint adhesion
- Provide protection against corrosion
- Increase lubricity of friction surfaces
- Facilitate mechanical deformation of metals
- Decorate—in many instances

Satisfactory protection of steel, zinc and aluminum surfaces against corrosion, paint peeling and blistering,



Typical automotive spray installation.

and hard wear requires precision methods of chemical conversion coating.

Types of Conversion Coatings

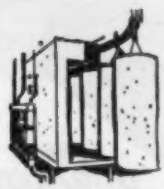
There are seven classes of chemical conversion coatings commonly specified and used throughout industry today. They are as follows:

Zinc-iron phosphate (Amchem Granodine). This is the heaviest type of coating (gray in color) used for prepaint treatments on steel, iron and zinc surfaces. The process requires five or six operations: cleaning; rinsing; rust removal, if necessary; coating; rinsing; and a second rinse. Coating weight ranges from 100 to 600 mg per sq. ft.

Medium or large volume production of automobile bodies, appliances, projectiles and cabinets can be handled effectively.

The coating solution improves paint adhesion by forming a crystalline deposit over the metal surface. This deposit is rough, as revealed microscopically, and so offers an ideal gripping surface for paint particles.

Manganese-iron phosphate (Amchem Thermoil-Granodine). This is a heavy black coating used on friction surfaces to prevent galling, scoring and seizing of parts. Typical metal parts treated are pistons, piston rings, gears, cylinder liners, camshafts, tappets and various small arms components.



Typical appliance treatment line.

Iron phosphate (Amchem Duridine). This is a comparatively new process that places a light coating on surfaces for improved paint adhesion. Since cleaning and coating occur in the same bath, it has only three to five stages.

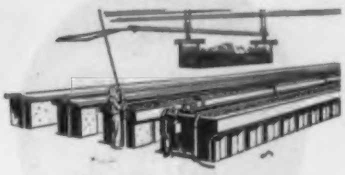
The iron phosphate treatment is a spray process suited for medium to large volume, large or small work. Precleaning is normally unnecessary, an economy factor in its favor.

Products protected by this process are steel or iron fabricated units, such as cabinets, washing machines and refrigerators. Weight of coating is 50 to 100 mg per sq. ft.

Zinc phosphate (Amchem Lithoform). This is a crystalline coating produced on galvanized iron and other zinc surfaces—also cadmium—for improving paint adhesion. The purpose of the coating is to provide a paint-gripping surface and to prevent the reaction between acidic components of the paint and the zinc metal, with the formation of soaps and loss of paint adhesion.

This coating is applied in weights of 75 to 500 mg per sq. ft. There are no limitations on volume or production or on size of products treated. Zinc phosphate coating is used on zinc alloy die castings, zinc or cadmium plated sheet or components, hot dip galvanized stock, and Galvanneal.

Amorphous phosphate (Amchem Alodine). This a protective coating for aluminum and aluminum alloys.

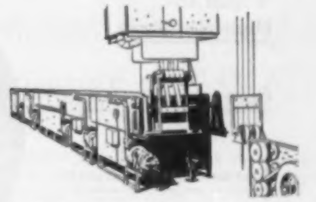


Typical aircraft dip installation.

It may be used in place of anodic deposition for improved paint adhesion and corrosion resistance.

This coating is practical for production in any volume. Coating weight is 100 to 600 mg per sq. ft. Products treated include aluminum awnings, doors and windows, aircraft and aircraft parts, missile parts, roofing and siding. Particularly good when aluminum is painted prior to forming.

Zinc-iron phosphate for oil absorption (Amchem Permadine). This is a relatively heavy coating adapted to the retention of rust-inhibiting drying or nondrying oils and waxes on ferrous metal surfaces. The coating is applied to a weight of 1000 to 4000 mg per sq. ft.



Typical continuous strip line installation.

The process is satisfactory for large or small work in any volume—nuts, bolts, hardware, guns, tools, etc.

Zinc-iron phosphate for metal forming (Amchem Granodraw). This is a specialized coating used in conjunction with a suitable lubricant to facilitate the cold mechanical deformation of steel. The coating acts as an anchor for the lubricant throughout drawing, extrusion, and cold forming operations.

It is a successful treatment for products such as blanks and shells for cold forming, heavy stampings, impact extruded shapes, drawn wire and tube.

For more complete information about any one or all of these chemical conversion coatings, contact an Amchem sales representative or write us at Ambler 23, Pa.

AMCHEM PRODUCTS, INC. (Formerly American Chemical Paint Co.)

AMBLER 23, PA. • Detroit, Mich., St. Joseph, Mo., Niles, Calif., Windsor, Ont.

Personals . . .

Harold C. Burgess, Cleveland district sales manager for Latrobe Steel Co., Latrobe, Pa., for the past 21 years, has been named Ohio regional sales manager for the company. In his new position, he will supervise sales and warehousing activities in Cleveland, Dayton and Toledo, and will continue to make Cleveland his headquarters. Succeeding him as Cleveland district manager is **M. W. Saxman III**, who has served as assistant district manager since his transfer from Latrobe in 1957.

The Aristoloy Steel Div. of Copperweld Steel Co., Warren, Ohio, has opened a new district sales office in Pittsburgh, headed by **John O'Conner III**, formerly Copperweld representative in Cleveland. At the same time, **James D. McKinnon**, district manager for Aristoloy's Chicago office, was named district sales manager of the Detroit district office.

C. F. Hood, who recently retired as president of U. S. Steel Corp., was elected an honorary vice-president of American Iron and Steel Institute recently.

William K. Murray has been promoted to manager of marketing for Enthone, Inc., New Haven, Conn., a subsidiary of American Smelting and Refining Co. Mr. Murray joined Enthone in 1953 and was supervisor of the technical service laboratory for several years before becoming manager of customer service in 1957.

R. T. Picha has resigned as metallurgist with the aeronautical division of Minneapolis-Honeywell Regulator Co., Minneapolis, Minn., to become president of Flame Heat Treating, Inc., a new commercial heat treating concern.

Max G. Manker has been appointed district sales manager for the Chicago area of the Aristoloy Div. of Copperweld Steel Co., Warren, Ohio, while **J. Robert Waters** has been named district sales manager in Philadelphia. Mr. Manker was formerly Copperweld's district manager in New York and Mr. Waters was chief of Copperweld's service department in Warren.

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gives you up to 200 mg/sq. ft. of zinc phosphate coating in 2 short minutes at 95° F.

The Turcoat low temperature phosphating process provides permanent paint adhesion when used at an economical, easy-to-maintain temperature of 95°F. This temperature is *lower* than that required by other "cold" phosphating processes. It is up to 75° *lower* than temperatures required by conventional phosphating processes. You save up to 75% in steam, water, electricity and downtime costs alone!

As a base for paint, the Turcoat low temp phosphating process provides a uniformly smooth coating of up to 200 mg/sq. ft. in two minutes at 95°F. **As a base for corrosion prevention,** it provides an 1100 mg/sq. ft. coating in just eight minutes at 95°F.

Turco has waited to announce low temperature phosphating until it was thoroughly perfected and proven, through exhaustive field testing, to be the very best. For this reason, you'll find that with this new process, just as with Turco's hundreds of other cleaning and chemical processes, you are assured of trouble-free operation, ease of control, and dedicated technical service...anytime, anywhere! Write today for the full story of Turcoat low temperature phosphating, along with Turco's phosphating reference chart. There's no cost ... no obligation.

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Metals Engineering Digest

. . . Interpretative Reports of World-Wide Developments

Advances in Fabrication Techniques Revealed at Southern Metals Conference

Notes on papers presented at the Southern Metals Conference, sponsored by Savannah River Chapter, Augusta, Ga., May 1959.

FABRICATION of newer types of materials for aircraft, missile and electronic applications is spurring interest in new welding methods. Progress being made in ultrasonic, electron beam and plasma jet welding was discussed at the Southern Metals Conference, sponsored by the Savannah River Chapter and held in Augusta, Ga., by R. M. Gustafson, research engineer, Bureau of Aeronautics. Mr. Gustafson also told about the development of electrodes for welding ultra-high-strength steels.

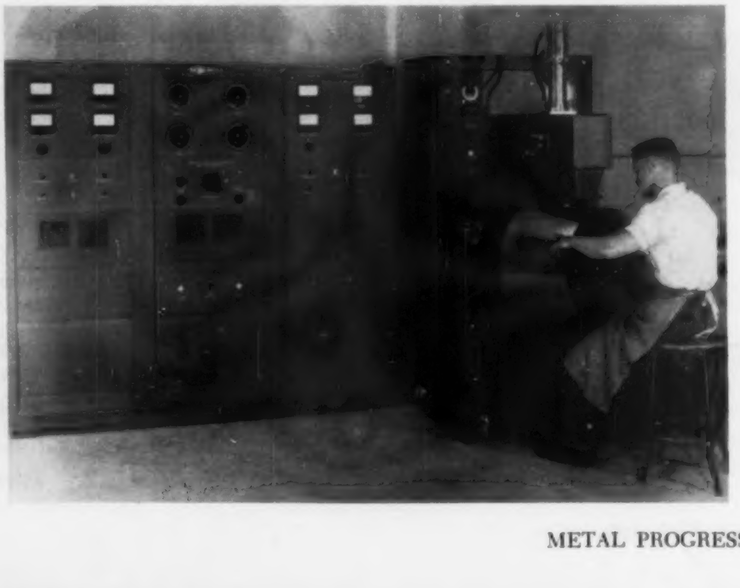
Ultrasonic Welding – This is a method of bonding similar or dissimilar metals at a temperature below their fusion point by introducing vibratory energy into the area to be joined. The frequency spectrum which has received greatest attention lies between 3000 and 85,000 cycles per sec. although vibratory welds can be made at lower and also at substantially higher frequencies.

In the process, pieces to be joined are clamped at low pressure (50 to 100 lb.) between two welding members (Fig. 1) called sonotrodes, and vibratory energy is introduced for a brief interval – generally 1 to 2 sec. Solid-state metallurgical bonds are produced with relatively slight deformation of the pieces being joined.

The fact that excessive heating and melting are avoided makes the ultrasonic approach to joining very attractive. The result should be improved ductility and shear strength and better corrosion resistance for welded joints. Mr. Gustafson showed photomicrographs of welds made in 2024 aluminum alloy by the resistance method and by ultrasonic means. In the cross section of the ultrasonic weld, there was no evidence of cast structure or nugget discontinuity. Also, there was no heat-affected zone and no appreciable deformation.

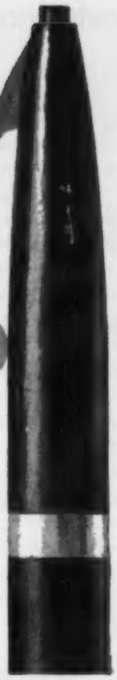
Equipment Needed – A transducer-coupling system is required for delivering ultrasonic energy into the weld zone along with an ultrasonic power source. Also required

Fig. 1 – This Ultrasonic Welder Is Being Used to Splice an Aluminum Cylinder With Overlapping Spot-Type Welds, Making a Leaktight Seam. (Courtesy Aeroprojects, Inc.)



ON THE BALL 500,000 TIMES A DAY BRIDGEPORT Free-Machining Brass Rod!

Because ball point pens are in everyday use, production of vital brass tips becomes astronomical along with quality control problems.



These tips — one of which is shown much enlarged — are produced at ultra-high speeds. The brass rod needed for them must be flawless in every respect. *Consistent* metallurgical composition, *precise* dimensional tolerances and *unvarying* standards of machinability — if any of these qualities vary even a fraction, production comes to a frequent and costly halt.

That's why Revere Metal Art Co., Inc., New York City, specifies Bridgeport Free-Machining Ball Point Pen Brass Rod for these inserts. It meets all requirements for precision, straightness, workability, machinability and tolerances —and, in addition, provides a surface finish that keeps finishing time and costs to a minimum.

Whether you use rod, strip or tube, you can count—just as Revere does—on getting consistent quality every time you specify Bridgeport Brass Alloys. It will pay you to get the complete story. Call your nearest Bridgeport Sales Office or write us direct for a complete list of Bridgeport products—Dept. 4104.

Bridgeport

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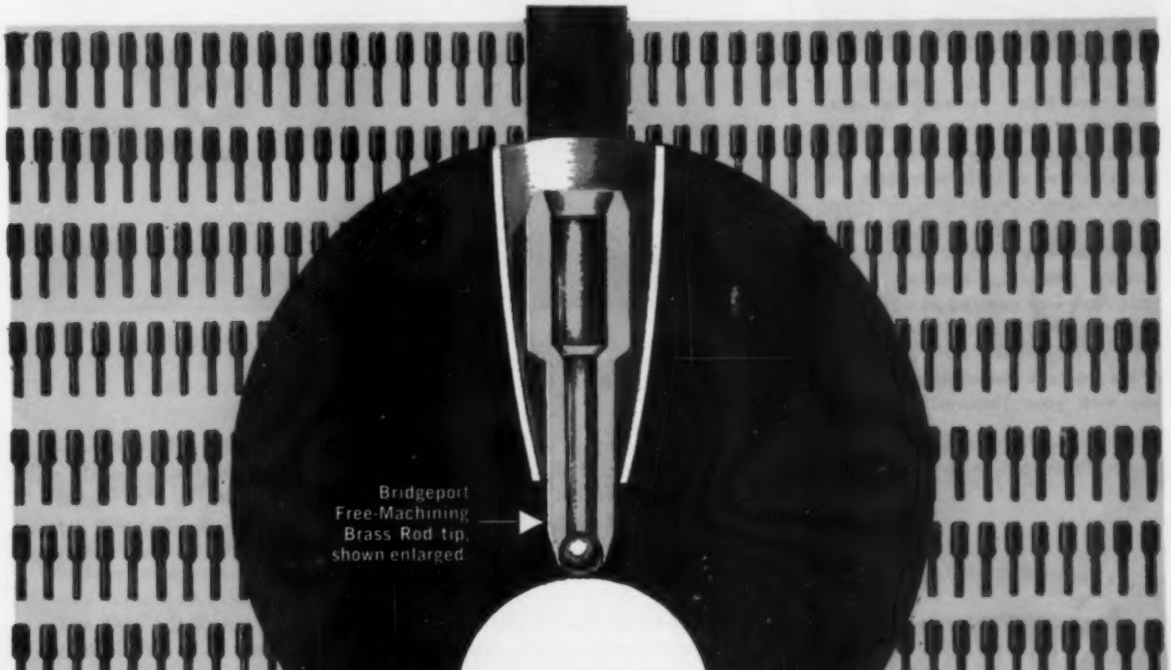

Metals Conference . . .

is a hydraulic system for lowering and retracting the welding head and a timing system for controlling the length of the ultrasonic pulse.

The simplest application of ultrasonic welding is the production of lap joints between sheets of metal, either by single spots or by overlapping spots to produce a continuous bond. A truly continuous weld seam can be made with rotating tips. To apply ultrasonic welding to a variety of geometric shapes utilizing different metals, it has been necessary to develop several basic types of welding equipment.

Scope of Use – Initially, the Bureau of Aeronautics was interested in ultrasonic welding for joining structural aluminum alloys; a great deal of work has been done not only on 1100 aluminum alloy but also on 2024 and 7075 alloys. Today, aluminum sheet with thickness up to 0.090 in. can be welded – a tremendous achievement because a few years ago only foil thickness could be joined. It is expected that with the development of more powerful equipment in the range 10 to 20 kw. heavier gages of metal can be joined. Two important features of ultrasonic welding emphasized by Mr. Gustafson were: (a) The process can join metals of dissimilar thickness; (b) foil can be joined to heavy sheet, plate or to heavy blocks of material. It also is valuable for joining dissimilar metals as illustrated by the apparatus in Fig. 2.

The Bureau of Aeronautics is sponsoring work to study the fundamentals of the welding process. It has been established that there is a plastic deformation at the interface caused by sheet vibrations, with resultant diffusion of the two surfaces. This mechanism is preceded or accompanied by a temperature rise in the weld spot. Precise temperature measurements have been made for different metals at the interface, varying from 200° F. in aluminum to 1500° F. in iron. Recrystallization has also been observed in ultrasonically welded joints on some materials.

Electron Welding Methods–Electron beam welding brings about fusion in a localized area by bombardment of parts with a beam of high-energy electrons. Operation in a vacuum provides an atmosphere many times purer than the best commercially available inert gases. Impurities in the metal, such as oxides, nitrides and carbides, which are not destroyed by heating in a vacuum are ionized to positive ions by electron bombardment. As positive ions they are lifted out of the melt and attracted to the grid of the electron gun. The result is a weld joint with exceptional cleanliness and ductility; the entire weld zone, not just the surface, is purified. Electron beam welding is being used primarily in the nuclear and electronics field. However, Mr. Gustafson predicted

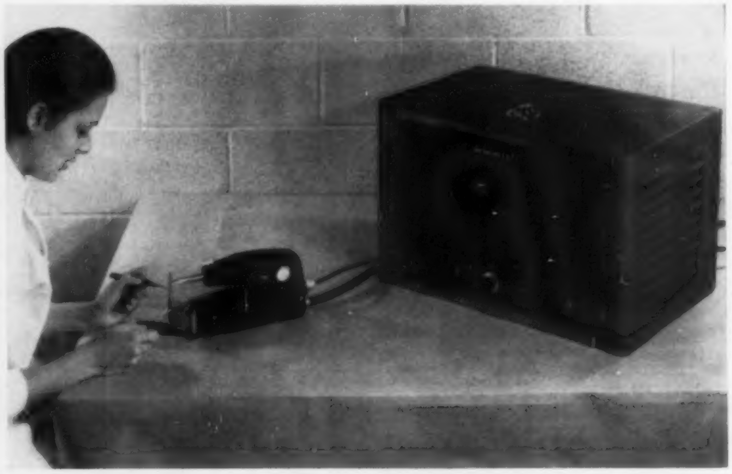

Fig. 2 – Ultrasonic Welding Is Valuable for Joining Dissimilar Metals. Here, very fine aluminum wire is being welded to germanium. (Courtesy Aeroprojects, Inc.)

Metals Conference . . .

that industry, in general, will employ the equipment more and more as the usage of refractory metals increases.

Plasma jet devices produce heat three to five times higher than the 6000° F. range given by the arc welding torch. A program has recently been initiated by the Bureau of Aeronautics to adapt the plasma jet principle to welding, which, if successful, should provide a new process with versatility unknown with other welding techniques.

Welding High-Strength Steels – Mr. Gustafson also reported that ultra-high-strength steels (for example, A.I.S.I. 4340 and H-11 die steels) can be satisfactorily fusion welded and heat treated to high strength levels (260,000 to 280,000 psi.) without appreciably affecting the tensile or impact properties of the base metal. In order to achieve this, welding electrodes have been developed which are capable of depositing weld metal compatible with the base metal on the basis of chemical composition, tensile properties, hardenability, impact resistance and microstructure.

Progress in Tungsten – In discussing general progress in metallurgy of tungsten, R. B. Fischer, Battelle Memorial Institute, reported that an important area of current research is the fabrication of sheet tungsten of large dimensions. The properties of tungsten are such that difficult problems are experienced. The high strength of the metal makes working difficult. Tungsten does not hold heat well; oxidation is another problem.

For many years attention has been on fabrication of tungsten filaments, wire rod and small dimensional sheet. For some contemplated uses, larger sheet is required. Tungsten has been slip cast, extruded and forged, and commercial parts are being produced by hot spinning and deep drawing. Dr. Fischer predicted that the availability of new shapes should create new uses for tungsten.

The ductility of tungsten came in for special mention. Dr. Fischer stated that fine tungsten wire and thin sheet can be prepared so as to have a small amount of ductility at room temperature. Thicker sections generally must be heated above 750° F. (sometimes as high as 3000° F.)

to obtain enough ductility for forming operations.

Purity Is Important – Recrystallization of tungsten usually gives a brittle product. The recrystallization temperature is about 3200° F. for commercial tungsten in moderately worked forms. Recrystallization embrittlement was not evident in high-purity molybdenum produced some years ago at Battelle, and Dr. Fischer felt this was encouraging because the same effect may hold for high-purity tungsten when recriptallized.

The evidence is clear that the grain boundaries of ordinary commercial molybdenum and tungsten behave in an unusual manner and are most sensitive to certain impurities. Dr. Fischer suggested that metallurgists wishing to use tungsten keep in mind that impurities and microstructural make-up of the metal can often have a very strong influence on the mechanical properties of the metal.

Porosity in Castings – This subject was discussed before the conference by F. N. Rhines, professor of metallurgy, University of Florida, who emphasized that one of the most common problems in the foundry is the control of porosity. The word "control" should be used advisedly because the elimination of porosity is an unrealistic objective – of doubtful value even if it could be accomplished – whereas the control of porosity is both necessary and feasible.

Porosity affects the mechanical properties by dividing the metal into a large number of parts. These respond individually to a tensile force by normal necking to failure and thus prevent the casting as a whole from exhibiting necking and other evidence of ductility.

Types of Porosity – Four geometric characteristics of casting porosity were considered: (*a*) number of pores, (*b*) their volume, (*c*) shape of pores, and (*d*) their location. Dr. Rhines emphasized that pore formation may be profitably viewed as a nucleation and growth process. The number of pores created and their location will then depend upon the rate, duration and circumstances of growth. Two and only two forces have been identified as being involved in pore nucleation and growth. These are the hydrostatic tension created by the shrink-

Metals Conference . . .

age of liquid metal, which is totally enclosed within a shell of solid, and the hydrostatic pressure exerted by gases present in supersaturation in the melt.

Of the factors involved in porosity, according to Dr. Rhines, gas content, time in the critical temperature range and hydrostatic head probably offer the greatest opportunity for exercise of control. In the matter of gas removal, it should be understood that it is virtually impossible to remove the last traces of a highly soluble gas, such as hydrogen, without boiling the metal – preferably in a vacuum.

Thus, according to Dr. Rhines, the practical foundry methods of gas removal, such as fluxing, remelting and vacuum melting, should not be regarded as means for gas elimination, but rather as a means for gas control. A considerable advance in porosity control could be made by using the gas removal processes to arrive at a predetermined gas content in the melt, rather than attempting to make the gas content as low as possible, regardless of the conditions involved.

The duration of the period of gas precipitation is to a large extent a characteristic of the alloy. It has been found that the volume of porosity increases directly with the temperature span of the freezing range of the alloy. Also, it is known that the volume of porosity increases in inverse proportion to the rate of heat extraction during freezing. However, with extremely slow freezing, a reverse effect is sometimes found, possibly associated with loss of gas to the exterior.

Control of Pressure – The use of positive pressure to control the hydrostatic head acting upon the growing pores (and thereby constrain both their nucleation and growth) has been practiced with some success. In the sand foundry, this can be done by placing the mold in a tank having suitable ports and supplying it with a liberal volume of high-pressure air (Fig. 3). The

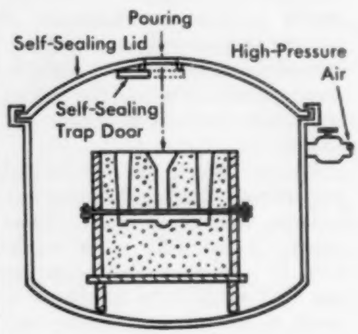

Fig. 3 – Diagram Illustrates How Positive Pressure Can Be Used to Control the Hydrostatic Head Acting Upon Growing Pores in Making an Aluminum Casting

metal is poured through a trap door which may then be closed and the tank inflated in a matter of seconds. By freezing the metal under pneumatic pressure, the total volume of porosity is reduced. While the individual pores are more numerous, they are much smaller and there is less tendency to form channel porosity.

A.G.G.

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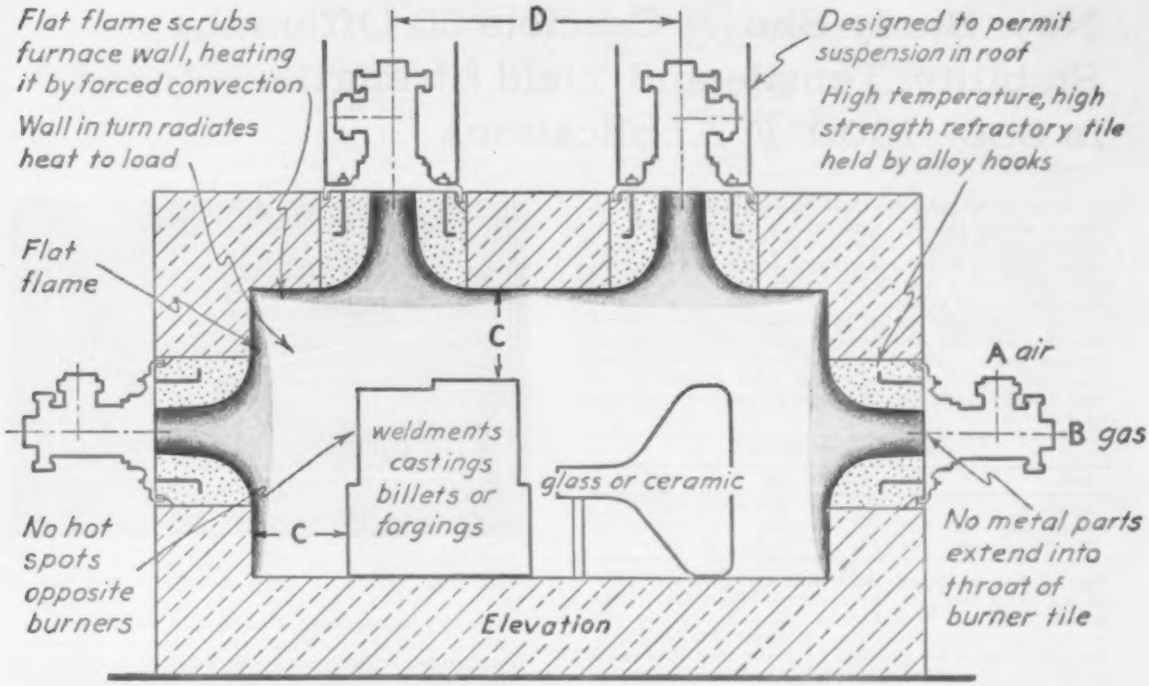

This Sketch shows how your North American Combustion Engineer might suggest using Flat Flame Burners to get the fullest use from your furnace — by putting a bigger pay load closer to walls and roof without flame impingement. (Figures for typical applications are listed in the table below.)

Each flame actually turns the corner of its specially shaped tile to give a temperature uniformity never before possible with so few burners. These nozzle-mix burners have an exceptionally wide turndown range and can be operated on correct air-fuel ratio or with excess air.

BURNER	A, Air Pipe Size	B, Gas Pipe Size	C, Suggested Min. Wall to Load	D, Suggested ℄ to ℄		Specifications
				Minimum	Maximum	
4832-2 & 4836-2	1¼″	1″	9″	13½″	30″	
4832-3 & 4836-3	1½″	1″	9″	16″	36″	Series 4832 has a
4832-4 & 4836-4	2″	1¼″	9″	18″	48″	13½″ square tile.
4832-5 & 4836-5	2½″	1½″	11″	24″	62″	Series 4836 has a
4832-6 & 4836-6	3″	2″	12″	27″	77″	24″ square tile.
4832-7 & 4836-7	4″	2½″	14″	33″	100″	

For engineering information, call your nearby North American Combustion Engineer or write for bulletins 48.32 48.36

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The North American Mfg. Co.
Cleveland 5, Ohio

Memo on Metals

New Study Shows Crucible 56 Offers the Stability, Tensile and Yield Strengths Needed in 800—1000° F. Applications

A recent study considers three steels which show promise of solving the high temperature strength problems encountered in today's high speed flight.† These problems of maintaining structural strength at elevated temperatures are further complicated by the need for favorable strength/weight ratios.

Two of the steels are hot work types (Crucible 218 and 56) that are only now being considered for structural applications in aircraft. Crucible 56 is a relatively new steel, offering an unusually high level of stability at high temperatures. The chemistries of the three steels are as follows:

CHEMICAL COMPOSITION

Grade	C	CR	Ni	Mn	Mo	V	Si	Al
Crucible 56	.40	3.30		.60	2.75	.40	1.00	
Crucible 218	.38	5.20		.35	1.40	.50	1.10	
AISI 4340	.40	.80	1.80	.70	.25		.30	

Figs. A and B compare the tensile and yield strengths of the three steels at the exposure temperature. The curves show that both Crucible 56 and Crucible 218 proved superior in these tests. However, the hardness-tempering curve for Crucible 56 shows that it is more stable than the other analyses evaluated. Crucible 56 also offers higher hardness (and hence, strength) when tempered in the 1050-1100° F. range. As the comparisons indicate, it also has higher elevated temperature tensile and creep properties than Crucible 218, which is a conventional AISI type. In Fig. C, the isochronous (constant time) stress-strain curves illustrate the stability of Crucible 56 at the top of the service temperature range. With these curves it is possible to determine the stress at which creep becomes an important consideration.

For further details on Crucible 56 and other comparative data, send the coupon.

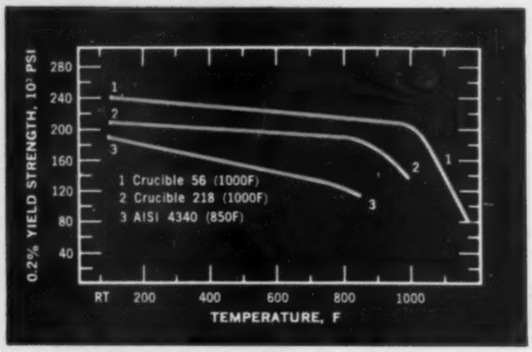


Fig. B. Yield strength (0.2% off-set) of various steels at exposure temperatures. Figures in parentheses are tempering temperatures.

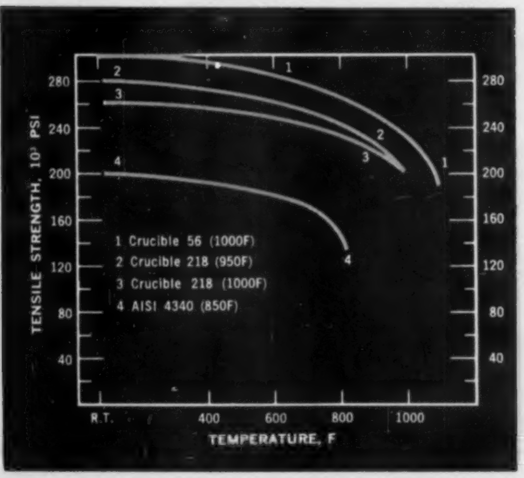


Fig. A. Tensile strength of various steels at exposure temperatures. Figures in parentheses are tempering temperatures.

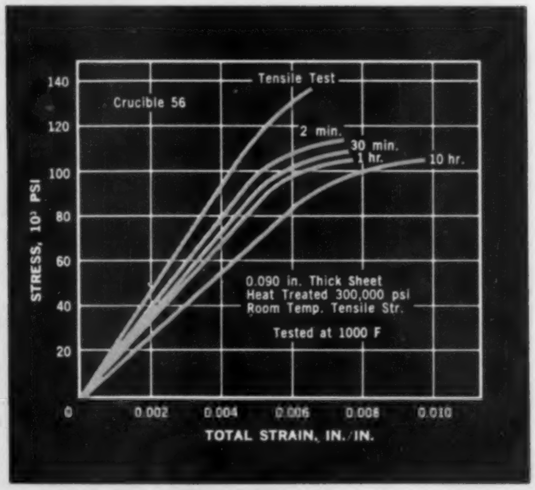


Fig. C. Isochronous stress-strain curves for Crucible 56 sheet show the outstanding creep properties of this steel which are higher than any other steel at 1000° F.

†Although this study considers only aircraft applications, data given here may prove helpful in designing turbines, chemical processing and nuclear equipment, and other equipment where service temperatures ranging from 800-1000° F. are required.

* *high temperature strength*
* *vacuum melting*
* *cast properties of UHS-260*

Compares properties of bearing steels produced by various melting techniques

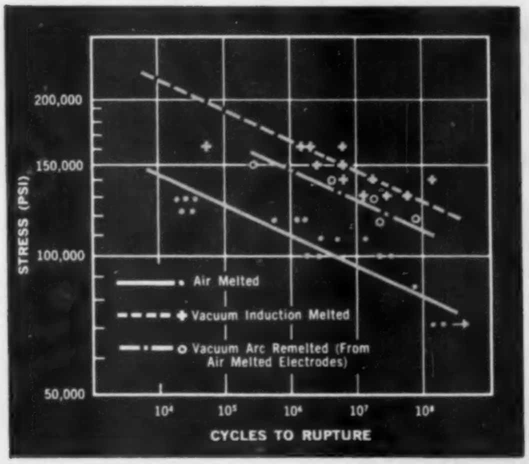
High vacuum technology has expanded considerably in recent years. The degree of improvement obtainable can be shown by comparing the properties of SAE 52100 produced by various melting techniques.

The following table givés gas content analyses of this chromium-carbon steel when produced by air melting (AM), air melting and vacuum arc remelting (AM+VAR), vacuum induction melting (VIM) and double melting (VIM+VAR):

Melting Technique	O(PPM)	N(PPM)	H(PPM)
AM	30	100	< 1
AM+VAR	7	70	< 1
VIM	5	3	< 1
VIM+VAR	3	3	< 1

Reduction in gas content is important, of course, because gases have varied detrimental effects on alloys. Oxygen increases transition temperature and forms various types of inclusions. Nitrogen effects aging, fatigue and stress rupture.

Similar improvement is obtained in cleanliness. (Inclusions strongly influence properties such as fatigue, impact and ductility.) Vacuum induction melted 52100 shows very small sulphide and oxide inclusions. Its background is extremely clean. Vacuum arc remelted 52100, made from air melted electrodes, also shows significant improvement over the air melted steel. Still further improvement is available with double melting.



Up to now, vacuum melted 52100 has been used mainly in bearings for jet engines, grinder spindles and instruments. It is credited with extending "B-10" life (the life at which 10% of the bearings fail) from 65 hours to 375 hours. Premature failures have been virtually eliminated. And the average number of production rejects of finished balls has dropped from 15% to 0.3%—savings that in some cases pay for the slightly higher cost of the vacuum melted alloy.

For more data on vacuum melted SAE 52100—or data on other vacuum melted ferrous and non-ferrous metals and alloys—send the coupon.

UHS-260 in cast form offers high strength with good ductility

New studies of the cast properties of UHS-260 should prove interesting to designers of structural parts for aircraft. In cast form at high temperatures, UHS-260 offers very high tensile strength with ductility equal to or better than transverse properties of the wrought form. Data from a preliminary report is given below. *For more complete information send the coupon.*

Grade UHS-260 Cast Properties —Preliminary Report

Nominal Composition

C	Si	Mn	Mo	Cu	Fe	Cr	Ni	V	Condition
0.35	1.50	1.35	0.30	–	Bal.	1.25	–	0.30	Hardened & Tempered

Mechanical Properties

	Test Temp °F.	Tensile Strength psi	Yield Strength psi	% Elong	% R.A.	Charpy Impact
Mean	–40°	265,000	218,000	6	10.5	7
High		268,000	226,000	6.5	15	8
Low		262,000	213,000	4	9	6
Mean	76°	260,000	217,000	4.5	12.5	7.7
High		265,000	241,000	6	16	8
Low		257,000	211,000	4	7	6
Mean	400°	266,000	191,000	5	7.3	11
High		269,000	205,000	6	10	13
Low		261,000	183,000	4	5	9
Mean	600°	237,000	162,000	9	18	11.3
High		240,000	172,000	10	23	12
Low		234,000	153,000	8	13	10
Mean	800°	200,000	147,000	9.6	29	12.3
High		232,000	179,000	13	42	13
Low		189,000	131,000	3	4	12

CRUCIBLE STEEL COMPANY OF AMERICA
Dept. EH09, The Oliver Building
Mellon Square, Pittsburgh 22, Pa.

Gentlemen:

Please send me the following:

1. Crucible 56 Data Sheet______ Comparative Data______
2. Data sheet on vacuum induction melted SAE 52100______
3. Data on other VIM metals______
4. Further information on the cast properties of UHS-260______

Name______

Title______

Company______

Street______

City______ Zone______ State______

CRUCIBLE STEEL COMPANY OF AMERICA

Arsenic in Steel

Digest of "The Effect of Arsenic on Mechanical Properties of Welds in Mild Steel", by D. Canonico and H. Schwartzbart, *Welding Engineer*, Vol. 43, November 1958, p. 32-35.

THIS REPORT describes the effect of various arsenic levels on the mechanical properties of weld beads in British and American steels. Welding fittings were forged from A.S.T.M. A106 Grade B steel.

The bursting strength tests involved vessels fabricated from commercial welding fittings and laboratory steels. Impact properties of laboratory steels containing various arsenic and phosphorus levels were also determined.

Commercial Welding Fittings

Commercial welding fittings, 45° long radius elbows, made from two heats of American and one heat of British steel, were welded into small vessels, illustrated in Fig. 1, using E 6010 electrodes and multiple passes as in customary production. All girth welds joining the pairs of 45° elbows were radiographed before the caps were welded on; they all proved to be sound. Three vessels, fabricated from the fittings of each manufacturer, were analyzed chemically and hydrostatically tested to destruction at room temperature.

The fittings made from British steel contained 0.060% arsenic (opposed to 0.003% arsenic in the American fittings), but there was no significant difference in the bursting strength of the vessels made from any of the three heats. The authors attributed the difference in strength to an actual difference in wall thickness, although all the fittings were of the same nominal dimensions. Ductile failures occurred in all vessels.

Bursting Strength of Heats

Three heats of steel conforming to A.S.T.M. A106 Grade B were induction melted and sand cast into 110-lb. ingots which contained various arsenic amounts at two general phosphorus levels. Each heat was killed with approximately 2 lb. aluminum per ton in the furnace. Arsenic was then added in the ladle.

Arsenic ranged from 0.020 to 0.201%, phosphorus from 0.009 to 0.065%. (*Continued on p.* 140)

Arsenic in Steel . . .

After grinding (to remove surface defects), parts of ingots 1 through 6 were forged to 3¼-in. diameter bars, from which 3-in. long pipes were machined to 2.875 in. O.D. and 2.469 in. I.D. Commercial-grade end caps were welded to these pipes, and the vessels were then hydrostatically tested to destruction at room temperature.

Arsenic did not appear to affect the bursting strength adversely and ductile failure in a longitudinal direction was similar to that experi-

Fig. 1 – Burst Pressure Vessel Fabricated From 45° Long Radius Welding Elbows. Ductile failure occurred in a longitudinal direction

enced in vessels fabricated from commercial fittings.

Impact Studies

For impact studies, ingot material was forged into plates 5 in. wide and ⅝ in. thick. With an E 6010 elec-

METALGRAMS

. . . news about metals and metal chemicals

UNION CARBIDE METALS

Electromet brand ferroalloys, pure metals and metal chemicals

Recent harbingers of increased demand for tantalum metal are its improved weldability and availability in large sheets. These advances combined with tantalum's excellent corrosion resistance indicate wider use in pharmaceutical equipment where corrosion and product contamination must be minimum, and in the chemical processing industry for large reactor vessels. Continued prominence in the electronic industry is assured by tantalum's extreme heat resistance and the outstanding dielectric properties of its anodic oxide film. For more information, write for Bulletin TA1-P.

* * *

Tungsten carbide powder is now available from Union Carbide Metals for evaluation in the manufacture of cemented or sintered carbide tools, dies and other compacts. Produced by a patented single-stage process, it meets existing particle size and chemical specifications for powders now produced by conventional methods. Data Sheet WC1-P gives additional facts.

* * *

The pace toward wrought chromium has quickened. Chromium metal has been successfully extruded into rod, tubing, and flat stock by Nuclear Metals, Inc., using ''Electromet'' chromium. Starting materials for these extrusions have been 3/4 in. by D high-purity chromium flake and 325 mesh by D laboratory grade powder. Write for Data Sheet CR1-P.

* * *

Applications of chromium monoboride are being explored with prospective users by Union Carbide Metals Company's field men. The compound's low volatility and high reflectivity make it attractive for several purposes. Coatings of chromium monoboride can be applied by metallizing methods. Evaluations of these coatings have proved them satisfactory where resistance to high temperatures, erosion, and corrosion are required. Chromium monoboride has also been used as a constituent of super alloys, such as those containing alloys of chromium, nickel and boron. Data Sheet CM1-P gives additional information.

* * *

The stringent demands of nuclear applications have brought increasing interest in columbium's high thermal conductivity, corrosion resistance, and low nuclear cross-section. Further demand is assured by a new series of columbium-base alloys being developed to withstand temperatures in excess of 2000°F. Significant quantities of several alloys are already being prepared. Write for Bulletin CB1-P.

* * *

Engineers and scientists can now obtain high-purity titanium carbide with less than 0.3% free carbon, and close to the theoretical composition of TiC. Makers of cemented carbide cutting tools may find in this product a way to simplify quality control problems, since the reproducibility of composition is excellent. Union Carbide Metals field men are consulting with users to develop several applications for this product. Write for Data Sheet TC1-P.

* * *

Union Carbide Metals Company, Division of Union Carbide Corporation, P. O. Box 330, Niagara Falls, N. Y. In Canada: Union Carbide Canada Limited, Toronto.

Arsenic in Steel . . .

trode, a weld bead was laid along the longitudinal center line of the plate. Charpy V-notch specimens were then cut from the plate with the notch base located at the interface of the weld metal and the heat-affected zone. (This was located by etching.)

The authors measured the transition temperature range by relating the energy absorbed to the testing temperature (Fig. 2). They were on less sure ground, as they readily pointed out, in evaluating the effect of arsenic on the transition temperature. Their sample was small and the effects of differences in phos-

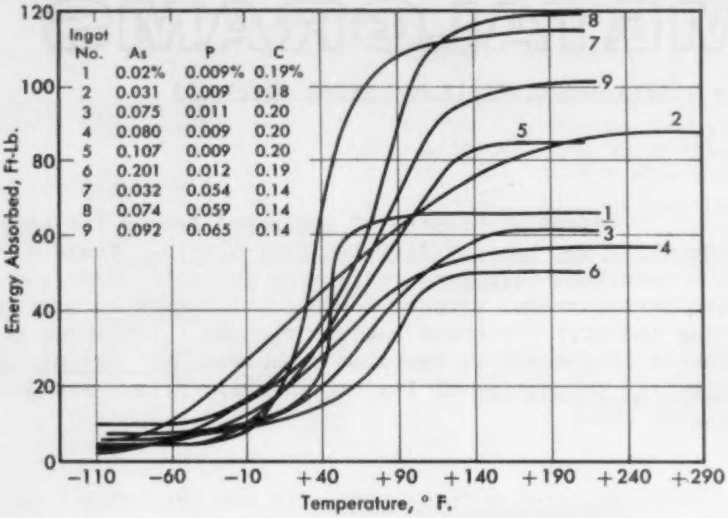


Fig. 2 – Standard V-Notch Impact Data Showing Effect of Arsenic

phorus and carbon levels complicated the picture. With reservations, they concluded that 0.1% arsenic raises the transition temperature only about 2.7° F.

D.R.

Vacuum Cast Steel

Digest of "The Importance of Vacuum Casting in the Steel Industry", by Z. Eminger, Dr. F. Kinsky and Z. Kletecka, *Czechoslovak Heavy Industry*, No. 2, 1957, p. 3-20.

THE PRESENCE of dissolved hydrogen and oxygen in liquid steel affects its solidification characteristics. Solubility for either element decreases with temperature so some gas is usually liberated during freezing. For example, the solubility of hydrogen in iron drops about 45% in the liquidus-solidus range of temperatures. Because the viscosity of the melt increases as temperature decreases, some hydrogen is likely to be trapped between dendrites as freezing progresses. This can cause porosity and growth of ingots or castings. Even more important, high hydrogen contents impair the ductility of solid steel and promote cracking and flaking. Consequently, metallurgists in many countries have investigated procedures for lowering the gas contents of liquid steels.

To insure freedom from flaking, hydrogen contents should be below 2 ppm. This corresponds to about 25 or 30% of the levels typical for

Vacuum Casting . . .

Czechoslovakian acid electric and basic openhearth steels. It is technically feasible to prevent flaking by using suitable in-process annealing treatments and controlled cooling practices. However, the time required to remove hydrogen to tolerable levels increases in proportion to the square of the section. This makes it impractical in production operations on large sections.

The simplest method of removing hydrogen from steel is to use vacuum pouring and casting techniques. A vacuum corresponding to a pressure of about 5 mm. mercury is theoretically capable of lowering hydrogen contents to 2 ppm. The low pressures characteristic of vacuum treatments also remove oxygen, by the C-O reaction, and nitrogen from steel.

Preliminary studies, started in 1955, indicated that vacuum treatments lowered the oxide inclusion contents by 30% and hydrogen levels by 50 to 75%. The authors also observed that vacuum casting produced a finer structure throughout the ingot cross section than that typical of conventional ingots. Presumably for that reason, vacuum cast steels were less sensitive to overheating.

This preliminary casting work led to the installation of production facilities for vacuum casting ingots weighing up to 110 tons and for degassing ladles holding 50 tons of steel. The production equipment is capable of pumping 5900 cu.ft of gas per min. at a pressure of 1 mm. mercury.

Experiments with this equipment indicated that noticeable improvements in quality can only be expected when pressures below 6 mm. mercury are attained. The hydrogen content of 5-ton ingots decreased another 30% if the vacuum was maintained for 20 min. during solidification instead of for 3 min. The authors do not consider this a practical procedure for commercial operations, however.

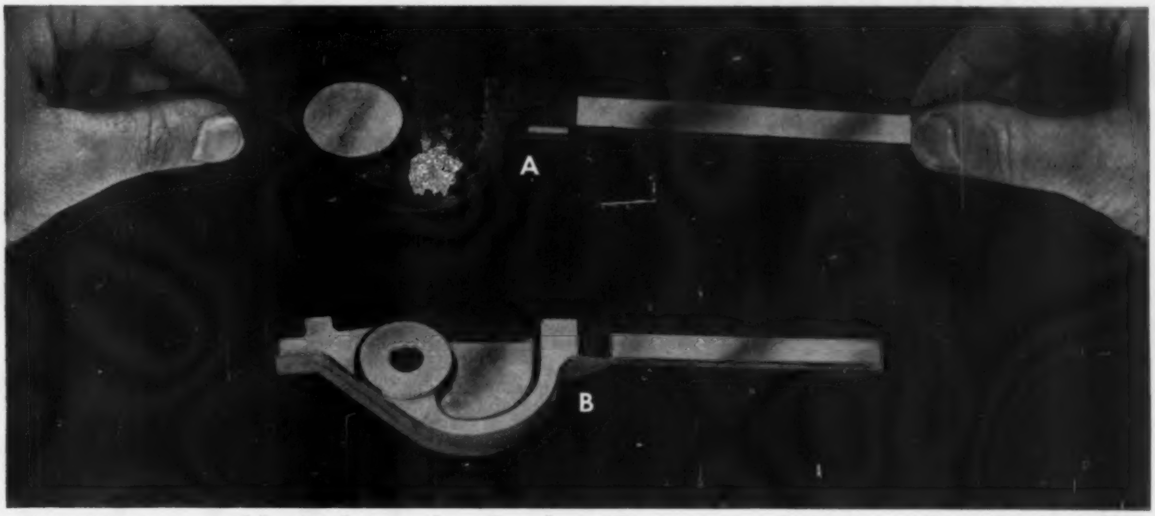
Vacuum cast ingots of 4% Si transformer steel were less porous than normal.

This distortion of elements throughout the cross section of Ni-Cr-Mo ingots was not subsequently

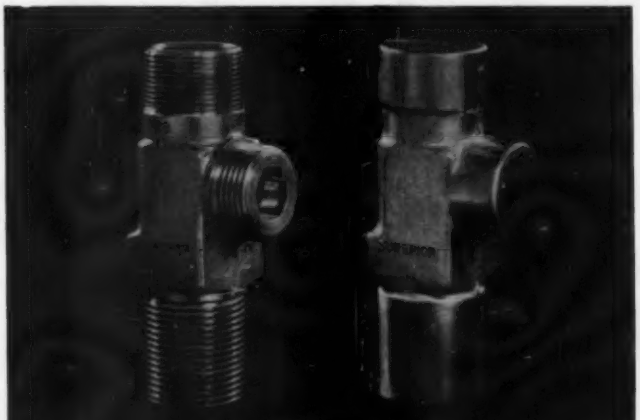
(*Continued on p.* 148)

QUALITY CONTROL PLUS SAVINGS

Value analysis suggested the use of a die-pressed forging. The result: an 85% cost reduction and a stronger, tougher part.



SWITCH BLADE in overspeed limiting device on large General Electric motor-generators was originally an assembly **A**—an arm brazed to a brass casting which was machined, slotted, and drilled. After review in the company's Value Analysis program, assembly was replaced by Anaconda die-pressed brass forging **B**. The superior strength of twice-wrought metal made possible a one-piece part. The excellent finish and consistent dimensional accuracy of the die-pressed forgings eliminated all machining but the drilling operation. The over-all cost is 15% of the original part.



VALVES FOR CHLORINE AND FLUORINE shipping containers must have unusual corrosion resistance and high strength. Superior Valve & Fittings Co., Pittsburgh, specialists in handling halogens, looked for a forging alloy that would be suitable. American Brass Company metallurgists suggested die-pressed forgings of a slightly modified Everdur®-1014, an aluminum-silicon bronze, for this chlorine-fluorine service, and this customer is finding wide use for it in other severe service, too. The twice-wrought metal of Anaconda die-pressed forgings has dense structure to prevent leaks—strength and toughness to take rough handling. Yet it can be machined in automatic-chucking machines resulting in good cost control.

THE vital job of controlling quality *and* costs may be easier than you think. Anaconda technical specialists will gladly help you find the right alloy and mill form to do both. See your American Brass Company representative or write: The American Brass Company, Waterbury 20, Conn. In Canada: Anaconda American Brass Ltd., New Toronto, Ont.

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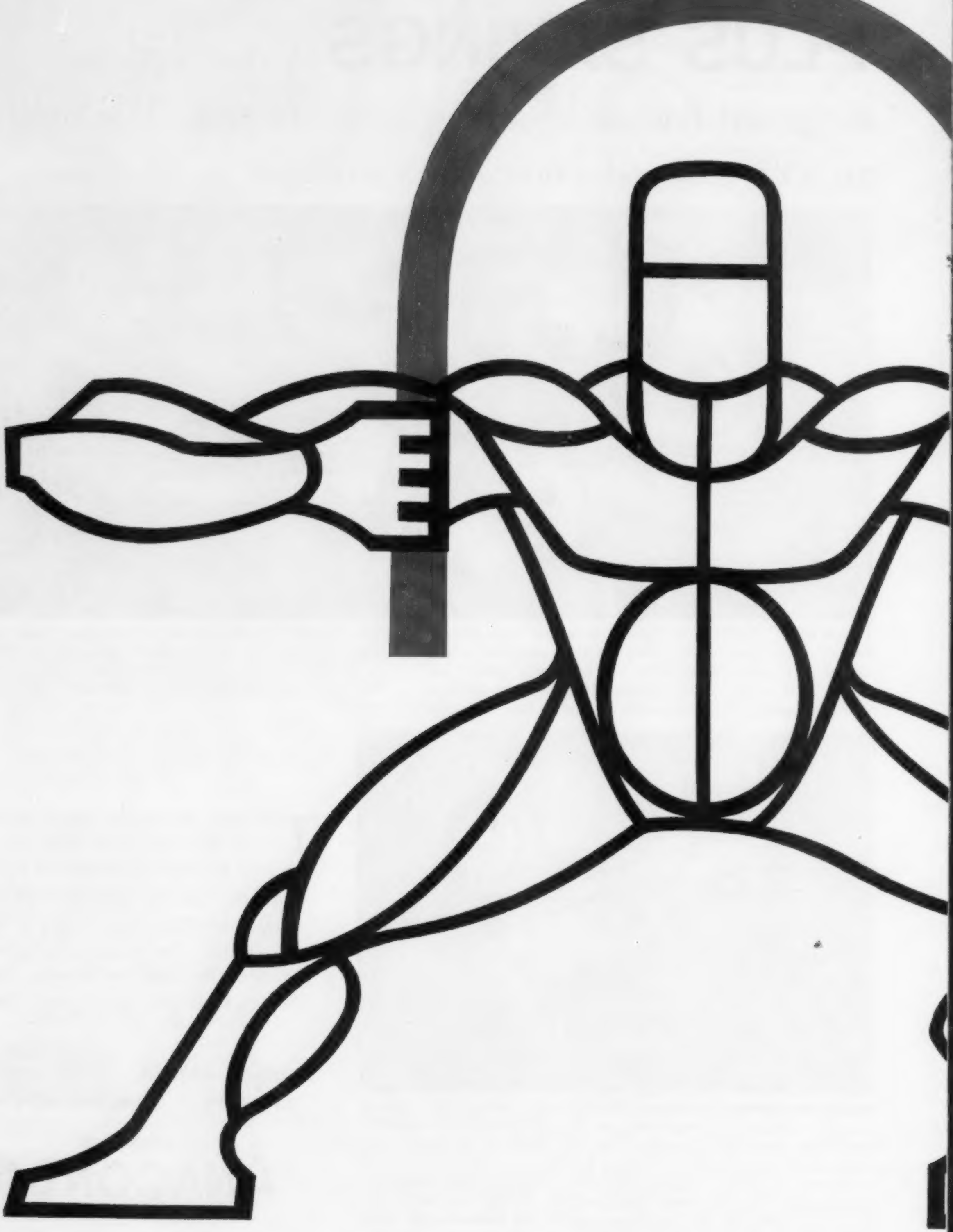

Vacuum Casting . . .

influenced by vacuum casting. Sulphur prints, however, indicated that vacuum-treated ingots had shorter pipes and smaller V-shaped segregates. Furthermore, the width of the regions in which axial segregations occurred at the top and bottom of the ingots was increased by the vacuum treatment. These effects were more pronounced in ingots which had been treated for longer times.

The vacuum treatments also influenced the primary cast ingot structure. The thickness of the surface zone of columnar crystallization decreased with the pressure in the casting chamber and with longer treating times. The region of randomly oriented dendritic crystals, inside the columnar zone, was wider than normal. Furthermore, the size of the grains in that region and of the equiaxed crystals at the center was appreciably finer in vacuum-cast ingots.

The studies indicated that vacuum treatments minimize the effects produced by variations in pouring rates, ingot stripping times, and overheating. Hence they should result in more uniform ingot quality as well as preventing flaking. Mechanical properties of forgings made from vacuum cast ingots did not appear unusual. The amount of reduction produced by forging had more effect than casting practice on transverse properties.

F. W. Boulger

Aluminum Welding

Digest of "The Metallurgy of Welding Aluminum and Its Alloys", by W. I. Pumphrey and E. G. West, *British Welding Journal*, Vol. 4, July 1957, p. 297-306.

The authors discuss the influence of temperature, oxygen, and hydrogen on the quality of the weld in aluminum alloys.

The expansion of the metal during welding and its subsequent contraction during cooling may cause stresses in the metal. The heat-affected zone may lead to local reduction of mechanical properties or corrosion resistance. If the parent metal has been work hardened or heat treated before welding, the in-

crease in temperature will soften the metal locally. In heat treated parts, this may result in an appreciable local reduction in strength. The corrosion resistance of the heat-affected zone may be altered, and local heating may also result in grain growth in cold worked metal.

Aluminum oxide is always present on the surface of aluminum-base materials after exposure to the air. This oxide layer must be removed completely during the welding operation, otherwise it prevents globules of molten metal from coalescing, and this gives regions of inadequate fusion. Furthermore, oxide particles that may be trapped in the weld metal possess no ductility and lead to brittle failure of welds. In gas welding and metal-arc welding, it is necessary to use a mixture of halogen salts to remove this oxide.

Hydrogen may be taken up by the weld pool from the following sources: welding flame, arc, moisture on the surface of the metal, filler wire, flux and atmosphere. This hydrogen may cause porosity which is concentrated near the surface alongside the weld, and this may be sufficiently severe to produce blistering. Porosity reduces the strength of the metal appreciably and may also affect the tendency to cracking. The tendency to gas porosity is more severe as the thickness of the weld increases and as the speed of welding decreases. In aluminum-magnesium alloys the tendency to gas porosity increases as the magnesium content increases.

In the majority of commercial aluminum alloys, cracking may take place when welds are made under restraint. The cracking tendency may be reduced by using a filler material of a higher alloy content than that of the parent metal. Increasing the alloy content of the weld metal also results generally in the increased strength of the weld. Aluminum-magnesium alloys are commonly welded with a filler material containing 30 to 50% more magnesium than the parent plate. Care must also be taken to avoid undesirable elements being present, that is, sodium in aluminum-magnesium alloys. Another important factor in deciding the composition of the filler material in relation to the parent metal is the corrosion resistance of the resulting weld. Any increase in the quantity of al-

Al Welding . . .

loying metal tends to reduce resistance to corrosion. Subsolidus cracking, which has been observed in some aluminum alloys, can be reduced by taking special precautions during welding or by welding in the annealed or solution-treated condition followed by final heat treatment if possible.

Postweld treatment is undertaken on cast aluminum alloys only when the alloy is a heat treatable one; then, if practicable, the whole assembly is heat treated normally.

Soft, nonheat-treatable metals or alloys are given good uniformity and continuity across the joint by cold or hot working followed by annealing. The cast structure of welds in work hardened, nonheat-treatable metals or alloys can be similarly broken down by hammering. The strength of welded heat treatable alloys can be restored only by a full heat treatment of the welded assembly. Where this is impractical, some improvement of the welded area can be obtained by working the weld to give a wrought structure.

A. COUTURE

Tracing Casting Inclusions

Digest of "Study of Nonmetallic Inclusions in Castings, Using a Radioactive Tracer", by B. B. Gulyaev and others, *Foundry Trade Journal*, Sept. 18, 1958, p. 341-344; translated from *Liteinoe Proizvodstvo*, Vol. 8, August 1956.

MANY of the nonmetallic inclusions in castings are particles eroded from mold refractories and drops of ladle slag entrained in the pouring stream. Both sources of inclusions were investigated by using the tungsten isotope 185 as a radioactive tracer in refractory materials. The final location of the eroded or entrained radioactive material was determined by exposing X-ray film placed on the surfaces of the castings for a suitable length of time. The radiographs disclosed the radioactive material located within 0.24 in. of the surface. The test plates, approximately 2 × 10 × 20 in., were cast horizontally.

The erosive action of liquid steel was studied by incorporating the

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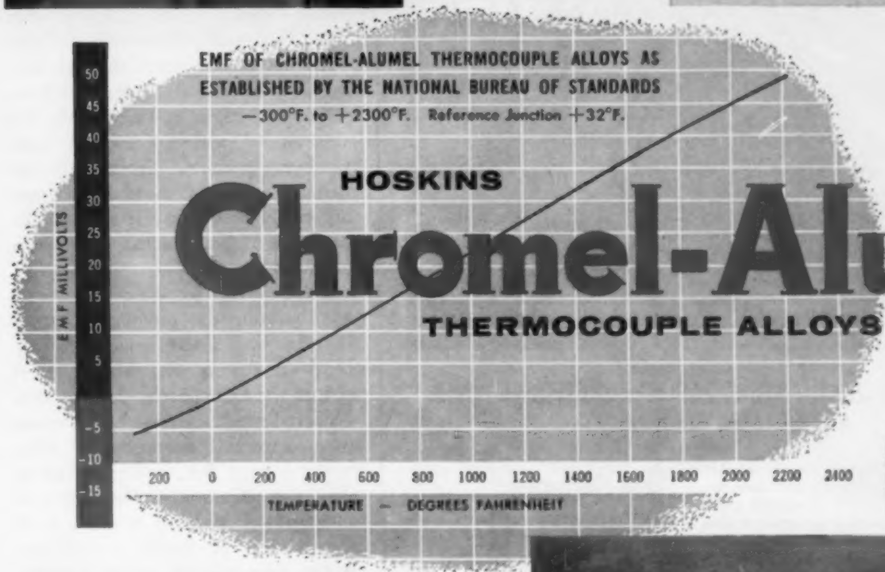

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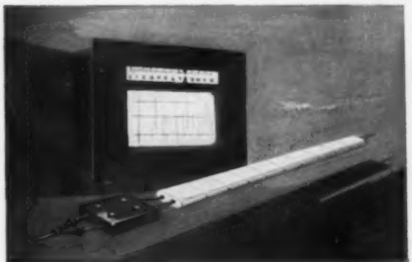

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Inclusions . . .

radioactive material in cores made from different molding mixtures. Cores made from oil-bonded mixtures, and water-glass bonded and clay-bonded green sand were placed in gates of different castings. Erosion was most severe with green sand gates and least severe with oil-bonded gates. Stronger cores were more resistant to erosion. Tests with low-carbon steel showed that raising the pouring temperature from 2750 to 2910° F. increased the amount of material eroded from sand-clay runners. Apparently the surface layers of mold refractories are easily eroded if metal temperatures are high and if the refractories are weak.

Experiments were also made by incorporating the radioactive tracer in refractory inserts placed in the base of the sprue. Three insert shapes were compared. Less erosion occurred when the base of the sprue was deep and semispherical than when it was flat or hemispherical with a depth equal to the radius of the sprue. Material washed from the bottom of the sprue concentrated near the top surface of the test plates. A few small inclusions were present near the bottom surfaces. Apparently they were too small to float to the top of stream in the time available.

The entrainment of slag was simulated by adding radioactive nonmetallics to the surface of the metal in the pouring cup. These experiments were made with iron. Inclusions of material added in the pouring basin concentrated at the bends or turns in the gating system and at the joint between the slag trap and riser. The larger particles that reached the mold floated to the top surfaces of the casting and were more numerous near the riser. The finer particles were trapped near the bottom surfaces of the castings. The amount of radioactive material trapped in the top layers of the plates was not affected by the three types of gating systems investigated. In these experiments, the maximum ratio of cross-sectional area of gate to sprue or vice versa was 1 to 1.4. Studies were made where sprue-gate-runner areas were uniform, continuously choking or continuously expanding. F. W. Boulger

Temper Embrittlement

Digest of "Temper Embrittlement in Nodular Cast Irons", by G. N. J. Gilbert. Paper presented at the annual meeting of the American Foundrymen's Society, Cincinnati, Ohio, May 1957.

A very extensive investigation of the effect of composition, heat treatment, rate cooling, and aging of nodular cast irons is given in this paper. Ferritic nodular cast iron, like malleable cast iron, sometimes becomes embrittled when quenched from 840° F. This is the temperature of galvanizing.

Altogether 16 different irons were studied. These varied chiefly in silicon and phosphorus, since increases in these elements increase the temper brittleness. Silicon varied from 0.93 to 2.73%. Phosphorus varied from 0.024 to 0.16%. All the irons were given a preliminary anneal, consisting of heating to 1650° F. for 16 hr., furnace cooling to 1270° F. and holding for 48 hr., and then furnace cooled. This was done to insure a completely ferritic structure with no pearlite present. The irons were then heat treated:

1. As annealed.
2. 1 hr. at 840° F. and quenched.
3. 1 hr. at 1200° F. and quenched.

Testing followed.

It is well known that quenching from 840° F. develops the maximum brittleness. Impact tests were then made at temperatures between +300° F. and −300° F. to determine the transition temperature for each iron at each heat treatment.

The low-silicon, low-phosphorus iron (0.93 Si, 0.024 P) showed a transition temperature of about −125° F. for all heat treatment. The high-silicon, low-phosphorus iron (2.73 Si, 0.028 P) showed a transition temperature of about +160° F. for the 840° F. quench and about +100° F. for the other heat treatment indicating the effect of silicon on the temper brittleness. The high-silicon, high-phosphorus iron (2.10 Si. 0.162 P) had a transition temperature of +300° F. for the 840° F. quench and +100° F. for the 1200° F. quench. This shows the profound effect of phosphorus in developing brittleness at 840° F.

Iron No. 6 (2.25 Si and 0.97 P) was subjected to various aging treatments to determine the effect on

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Embrittlement . . .

impact transition temperature. When this iron was quenched at 1200° F., it was ductile under all conditions. However, when subsequently heated at 840° F., it became embrittled after 24, 100 and 166 hr. One hour at 840° F. was not sufficient time to develop brittleness.

An iron containing 2.08 Si and 0.08 P plus 0.16 Mo was found to be ductile at all stages of heat treatment and aging. The presence of this amount of molybdenum practically eliminated the brittleness.

Irons treated but slowly cooled from 840° F. instead of quenched have their ductility progressively increased during this slow cooling.

A susceptible iron quenched from 1200° F. is more ductile than when slow cooled from this temperature.

Embrittlement induced by treatment at 840° F. in an iron slow cooled from about 1200° F. can be removed by quenching from a temperature of 1200° F.

The susceptibility of nodular cast iron to temperature embrittlement is increased by phosphorus and silicon, but phosphorus is much more effective than silicon. E. C. Wright

Gray Iron Inoculants . . .

Digest of "Inoculation of Gray Cast Iron", by N. C. McClure, A. U. Khan, D. D. McGrady and H. L. Womochel. Paper presented at the annual meeting of the American Foundrymen's Society, Cincinnati, Ohio, May 1957.

An extensive investigation of the inoculation of gray cast iron is described. About 20 250-lb. heats were melted and seven different inoculating agents were used. These are: ferrosilicon (92.7 Si, 1.7 Al, 0.3 Ca); calcium-silicon (64.0 Si, 31.7 Ca, 1.7 Fe, 1.1 Al); silicon-manganese-zirconium (62.8 Si, 2.2 Ca, 6.5 Mn, 5.5 Zr); silicomanganese (18.5 Si, 66.5 Mn, 13.0 Fe, 1.3 C); pure silicon; pure calcium; pure aluminum. The experimental procedure was as follows:

All of the heats described in this report were made in a 250-lb. indirect arc, rocking furnace. Charges in the cold furnace consisted of pig iron, structural steel, ingot iron punchings, and 27% ferrosilicon. Manganese and sulphur contents

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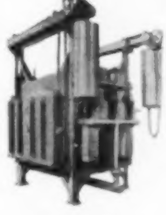

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Gray Iron Inoculants . . .

were adjusted immediately after the meltdown with additions of iron sulphide and 80% ferromanganese.

All melts were brought to 2850° F, as determined by optical pyrometer readings through the spout. This temperature was selected as being representative of general practice, and as providing sufficient latitude of temperature to transport the metal to the molds, skim the ladle, read the temperature with an optical pyrometer, and pour at the temperature selected for these experiments, 2650 to 2675° F.

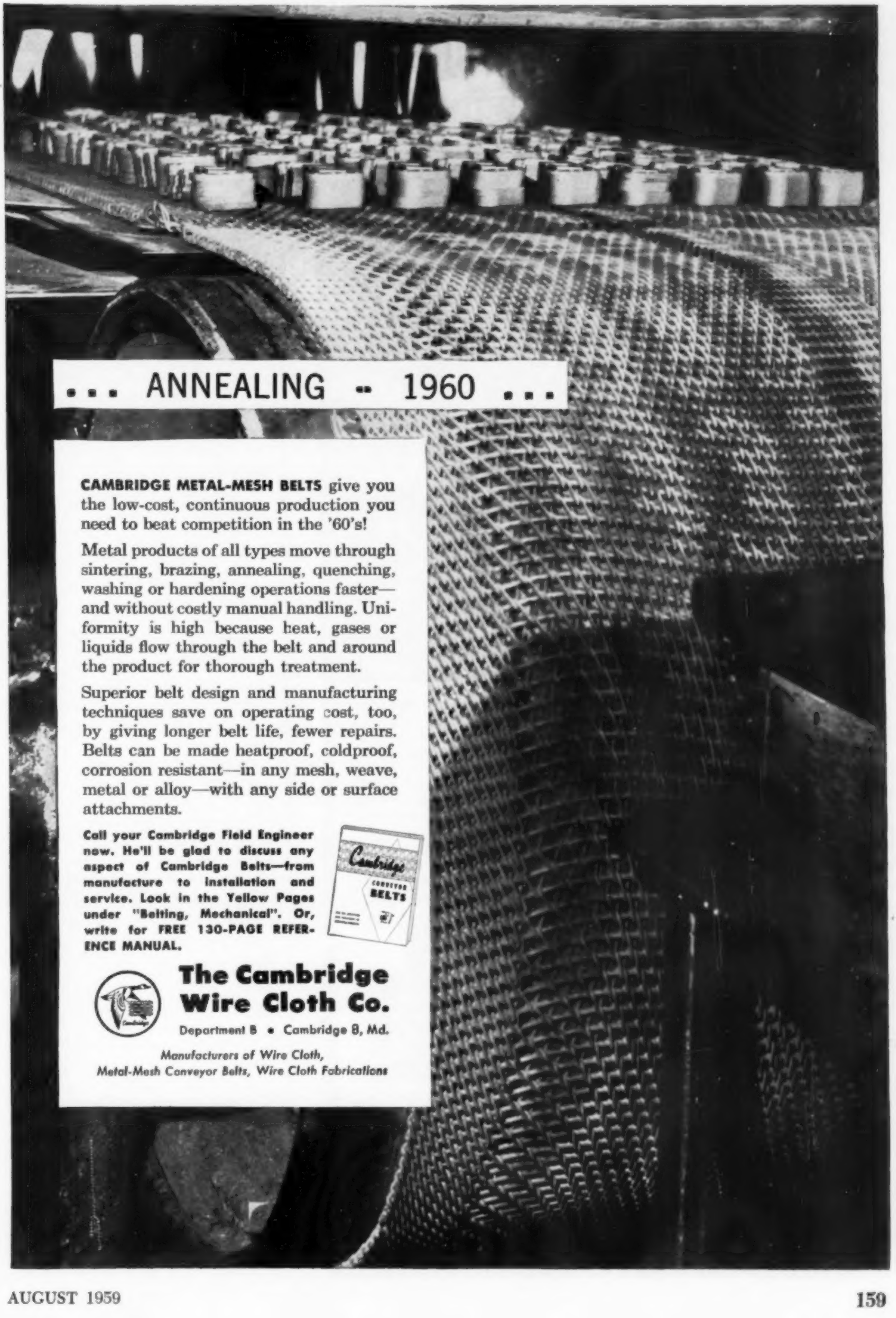
All ladle additions, unless otherwise indicated, were made by tapping a small amount of metal into the ladle and then adding the inoculating alloy continuously as the balance of the iron entered the ladle. During this operation, an effort was made to carry the inoculant under the surface with the molten stream.

In ladle treatments with active metals, special procedures were required. These will be described for the individual cases.

The time interval between tapping and pouring varied in general from 2 to 4 min. This time was required for the metal to cool from the tapping temperature, and for transportation, skimming, and determination of temperature.

Metal from each ladle was cast into vertical, dry sand-core 1.2-in. standard test bar molds, washed with a noncarbonaceous silica wash. These bars were broken on 18-in. centers in accordance with standard procedure. All transverse test bar results were the average of three or more bars. Bars showing defects in the fracture with abnormally low results for breaking load and deflection were not included in the average. The number of test bars poured varied from three to five. Bars were cleaned with a wire brush.

The influence of calcium was outstanding among all the various inoculating agents. For example, iron treated with ferrosilicon had a transverse strength of 2665 lb., a deflection of 0.208 in. and a tensile strength of 46,910 psi. The same iron treated with calcium had a transverse strength of 3728 lb., a deflection of 0.394 in. and a tensile strength of 59,200 psi. The great increase in property due to calcium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Gray Iron Inoculants . . .

was occasioned by the fact that most of the graphite was in the Type A distribution whereas the silicon treated alloys showed a tendency toward Type D distribution.

Silicon and silicomanganese (which was relatively free of calcium and aluminum) were not effective as inoculants.

The inoculating ability of various commercial grades of ferrosilicon increased with the calcium and aluminum contents. Low-calcium grades had very little effect.

The silicon-manganese-zirconium alloys containing somewhat more calcium than is found in commercial ferrosilicon were more effective than ferrosilicon.

The most effective inoculant for the improvement of mechanical properties in these experiments was the calcium-silicon alloy with approximately 30% Ca.

Metallic calcium additions to the ladle brought about marked improvements in mechanical properties and graphite distribution. With the exception of calcium-silicon, calcium was superior to all other inoculating agents tested in these experiments.

Metallic calcium was effective in reducing chilling tendency and cell size of cast iron microstructures.

Calcium additions reduced the carbon content of molten iron by formation of a carbide of low solubility; it is suggested that calcium carbide is involved in the mechanism of Type A graphite formation.

Although aluminum was a powerful chill reducer, its addition to cast iron did not promote Type A graphite distribution. Thus chill reduction is not necessarily associated with an improvement in the graphite distribution. E. C. WRIGHT

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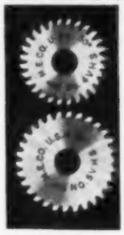

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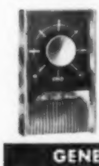

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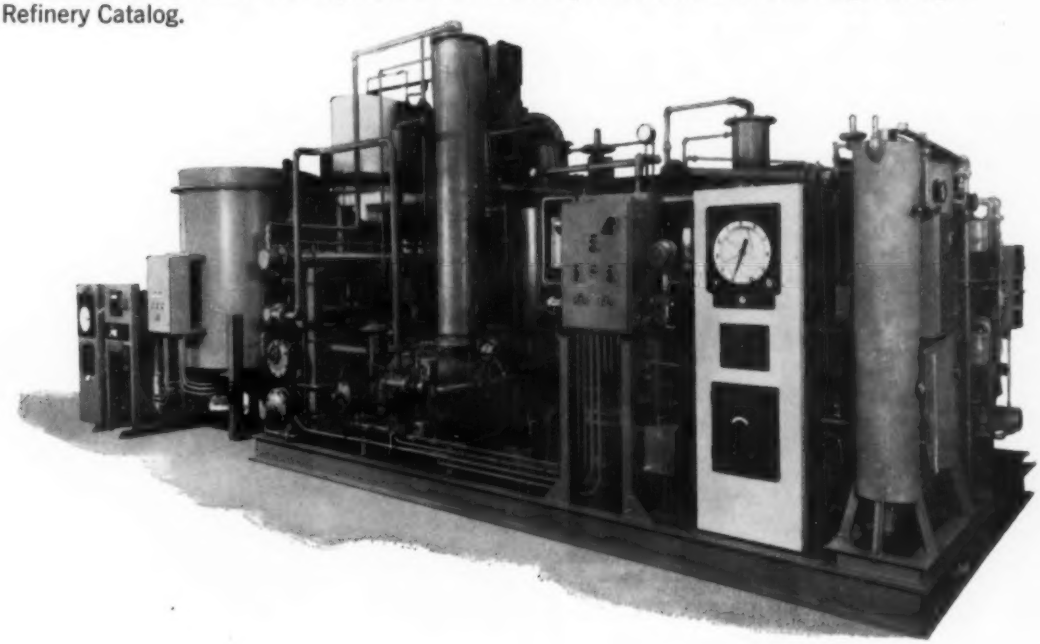

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Wear of Metals

Digest of "Wear of Metals", by F. T. Barwell, *Journal*, Institute of Metals, Vol. 86, February 1958, p. 257-269.

THE ANNUAL FINANCIAL LOSSES due to metal wear must be very substantial in any highly industrialized country. It is a problem now being attacked vigorously in a number of laboratories. This paper reviews current progress of one of the largest British groups located at the Mechanical Engineering Research Laboratory, near Glasgow.

Rolling Contact – Ball bearings operate under conditions of pure rolling where no wear should occur. Yet failure by pitting is common. The life under given circumstances shows considerable statistical spread but there is a general relationship with load. The origin of the pitting is clearly connected with high elastic stresses in the surface layers. Nevertheless, it is not simply a problem in mechanical fatigue because lubricants have a marked influence on its incidence. The reason for this is not clear. The lubricant may affect the stress distribution over a contact zone. Alternatively, a corrosion fatigue phenomenon may be partly involved on which the lubricant has an influence.

Scuffing – A machine has been devised which enables the investigation of the early stages and progressive growth of scuffing damage. The lubrication of surfaces subjected to intense pressures is being studied. It is believed that some slight elastic deformation of even the most rigid surface may occur. This may modify the hydrodynamic conditions to prevent actual metal-to-metal contact. Electron microscope investigations give evidence of plastic deformation of the scuffing track even in hard steels.

Torn patches of transferred materials are usually present on scuffed surfaces. This is attributed to the development of high temperatures at the points of contact causing local welding. But this cannot be the full story. The transfer can occur even under substantially hydrodynamic conditions of lubrication.

Fretting Corrosion – The first stage of fretting appears to be a plucking type of wear producing fine metallic particles. These oxidize in

Wear of Metals . . .

the presence of oxygen. The majority of the resulting debris cannot escape and so gradually increases in volume. This finally results in the separation of the two metal components. Milling of the oxide debris then enlarges pits in the two surfaces. The phenomenon may therefore be classified as one of wear in which the effects of air or other environment is of particular importance. This conclusion has led to experiments which indicate that the type and nature of the oxide on a surface has a vital influence even in simple sliding.

It is concluded that the study of any wear problem should be preceded by an analysis of the dynamic, geometric, kinematic and metallurgical factors involved. The metallurgical structure may be of great importance. It is likely that each phase in a microstructure makes its own contribution to a wear process.

L. E. SAMUELS

Strength of Spot Welded Joints

Digest of "Static Strength of Spot-Welded Joints", by A. N. Dorofeev, *Avtomaticheskaya Svarka*, Vol. 9, 1956, No. 2 (7), p. 58-66; Henry Brutcher. Translation No. 3802.

THIS TRANSLATION gives an insight into current Russian interest in adapting mathematical methods to the evaluation of stresses in special joints. The translation reports a significantly more basic approach to the determination of stress distribution in a weldment than has been noticed in reading through English-language welding journals.

It is common design practice to consider that static loads on spot welded joints are evenly distributed. Justification for this incorrect assumption has been that although initial stresses on the individual welds may be nonuniform, elastic and plastic strain applied to the joint will equalize weld-shear stresses. It can be shown, however, that with joints containing more than two rows of spot welds, the shear stresses in the spots are severely nonuniform. This uneven stress distribution exists

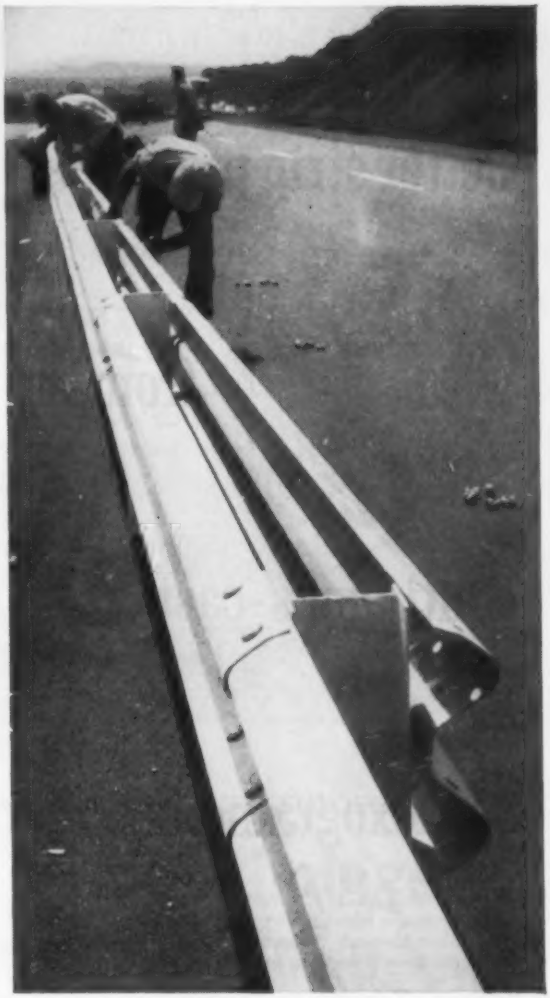
Hot-Dip Galvanizing Replaces Painting

...and Proves A Life Preserver For Highway Life Guards

It is estimated that road building to the extent of six billion dollars will make 1959 the biggest highway construction year since Congress, in 1956, authorized the 41,000 mile interstate highway system.

Last year, as a part of this continuing program, 11 miles of hot-dipped galvanized guard rail were installed on the Pennsylvania Turnpike near Somerset, Pa. The rail was galvanized after fabrication and delivered to the site as needed. Under normal conditions, construction crews installed an average of 3000 feet per day. For complete protection against atmospheric corrosion, galvanized bolts were used to fasten the rails in place. This type of double faced guard rail has become increasingly popular especially on older highways where narrow medial strips are a hazard.

Noteworthy is the proven fact that the ultimate cost of hot-dip galvanizing is lower than painting because it eliminates the recurrent expense of *re-painting*.



Here is an example

The hot-dip galvanized bridge railing shown here was installed on the Merritt Parkway near Milford, Conn. in 1938. *In the ensuing 20 years it has retained its appearance and strength without painting.* This is just one of the many installations where galvanized steel is saving the nation's Highway Departments millions of maintenance dollars every year. Thanks to the protective zinc coating, galvanized highway structurals are immune to atmospheric corrosion and have the added advantages which the inherent strength of steel provides.

ASTM SPECIFICATIONS

Steel products to be galvanized after fabrication, and approved for installation on inter-state highways, are covered by ASTM Spec. A123 and apply to:

- Bridge Structurals
- Decking and Railing
- Grating
- Fence Posts
- Sign and Reflector Supports
- Expansion Plates
- Rocker Plates
- Guard Rails
- Lighting Standards

NOTE: ASTM Spec. A123 corresponds in most cases to a similar specification of the American Assoc. of State Highway Officials, e.g., ASTM A123 is the same as AASHO Spec. M111-55.

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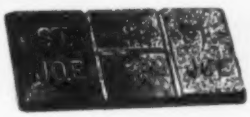


Spot Welding . . .

until fracture, and may cause unexpected failure.

The distribution of the static load between rows of spot welds can be most readily visualized by initially assuming unrealistic properties. If the sheets bonded together are absolutely rigid and the welds completely elastic, a uniform distribution of shear forces in the spots may be obtained. If, on the other hand, the sheets are completely elastic and the spot welds absolutely rigid, the entire load will be taken by the outside rows of spot welds. Although neither assumption can be completely true, the rigidity of spot welds in pure shear and the relative deformation of the sheet metal under tension combine to force higher loads into the outer rows of spot welds. Therefore the assumption that the total load would be carried by the outer rows may be more nearly true than the assumption of even shear stress distribution between the rows of spot welds.

Under conditions of strain hardening, the outer rows of spots will absorb increasing shear loads right up to their fracture stresses. As a consequence, the breaking load in pure shear of a spot welded joint is determined primarily by the characteristic strength properties in the region of the outer row of spots.

The exact distribution of shear loads between rows of spot welds would depend on the deformation characteristics both of the sheet material and of the welds. Calculations for mild steel weldments show that components containing three rows of spots should have approximately 74% of the static shear load carried by the outer rows of spot welds. When four or five rows are used, approximately 60% of the load is carried by the outer rows. When six or more rows of welds are used, the load becomes practically constant at 58%.

Any repeated shear loading on a spot welded joint increases the rigidity of the welds because of strain hardening. This hardening effect increases the disproportionality of the loading on the outer rows of spots, and thus lowers the strength of the entire joint. The effect of repeated loading on weld strength

Spot Welding . . .

characteristics should be determined experimentally.

The mathematical derivations reported in the translations are brief and difficult to follow. However, the final equation for the determination of stress in the end-rows of spots is directly usable within the limits of elastic strain, and can be applied with slight modifications to conditions of plastic strain.

D. W. Grobecker

Stress-Relieving Welded Specimens

Digest of "The Influence of Stress-Relieving on the Initiation of Brittle Fracture in Welded Plate Specimens", by R. Kennedy, *British Welding Journal*, Vol. 4, November 1957.

Because there is much controversy over the correlation between small-scale tests of the notch ductility of steel and service conditions, this study used large plate specimens. In cooperation with the British Welding Research Assoc., this program was conducted in the research laboratories of Colvilles, Ltd. The objective was an investigation of conditions for initiation of brittle fracture in 3 ft. square specimens (1 in. thick) having a central longitudinal butt weld with a saw-cut notch defect at its midpoint. Tests were designed to determine the effect of various stress-relieving treatments on the applied stress required for fracture initiation.

Mild steel plate, containing 0.18 C, 0.54 Mn, 0.019 P, 0.033 S and 0.04 Si, was chosen for the test specimens. A double-V, with a 70° over-all bevel from both sides using a ⅛-in. land and gap, was chosen for the butt weld joint. Rutile-type electrodes were used for all welds while the results were altered in some cases when low-hydrogen electrodes were chosen for the first pass only. Testing temperatures were generally —8° C. (18° F.) with low temperatures of —22, —25, —50 and —56° C. (—8, —14, —58 and —68° F.) achieved when necessary to effect fracture.

Different treatments tried were:

Furnace Stress-Relief — For stress-

Stress-Relieving . . .

relieving of local welding stresses, the specimens were heated to 650° C. (1200° F.), held for 1 hr. and cooled in still air. This proved to be the most effective treatment.

Low - Temperature Stress - Relief – In this process, two bands were heated, one on each side of the weld, to about 200° C. (390°F.) while keeping the weld relatively cool. This was accomplished by traversing two oxy-acetylene burners along a 4-in. width on each side of the weld at a speed of 10 in. per min. A 4-in. center width containing the weld was unaffected. Water sprays cooled the plate immediately behind the advancing torches.

While this procedure was partially successful in reducing brittle fracture, it was not as effective as thermal stress-relief carried out at 650° C. (1200° F.).

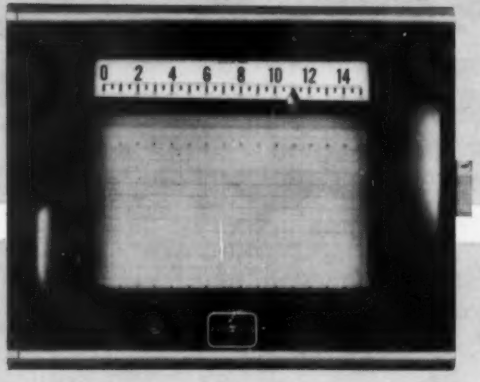
Mechanical Straining – This procedure applied a load until yielding (approximately 0.12% plastic extension) had occurred over the full section of the specimen. The load was applied after heating the specimen to 30 to 50° C. (85 to 120° F.) (above the brittle transition temperature for the steel).

Somewhat inconclusive when compared with untreated as-welded specimens, this method may be effective but is impractical for large weldments.

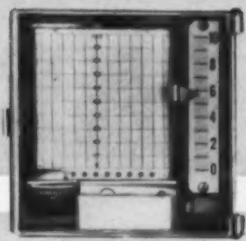
Preheating and holding the interpass temperature at 200° C. (390° F.) and during welding was of no value. Nor was the treatment of plates heated to 250° C. (480° F.) and held for 4 hr. at this temperature after welding of any value.

Local Heating of the Weld Region – This was a post - welding treatment after the specimen had cooled. The weld was reheated to about 650° C. (1200° F.) by oxy-acetylene torches applied simultaneously to both sides of the weld. Heating was rapid and temperatures were estimated. This method was also ineffective.

The investigators conclude that a major factor governing the initiation of brittle fracture in a welded structure is the residual stress arising from the welding process. Stress-relieving treatments provide safeguards against the initiation of such failures. The more effective the

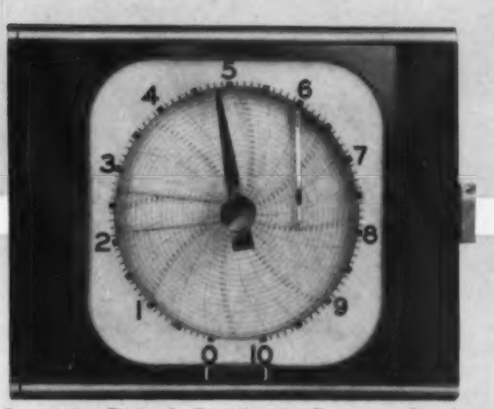


Dynamaster Electronic Potentiometer Pyrometer—Strip-chart model records on chart 11" wide, 120' long.



Miniature Electronic Dynamaster Pyrometer—Records on 3" strip-chart. Indicator model features easy-to-read 9" scale length.

Bristol Millivoltmeter Pyrometers—Free Vane* pyrometer controllers (shown) or indicating types. Many control modes available.



Dynamaster Electronic Potentiometer Pyrometer—Round-chart model records on 12" chart, indicates on extra large scale.

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stress-relief, the greater the safety afforded. Furnace treatment at 650° C. (1200° F.) is most effective and practical while local redistribution of residual stress is moderately beneficial.

O. T. Barnett

Low-Temperature High-Impact Steels

Digest of "Some Aspects of Melting Low-Temperature High-Impact Steels", by W. A. Koppi, International Nickel Co., New York, presented at the A.I.M.E. Electric Furnace Steel Conference, Pittsburgh, December 1957.

The A.S.T.M. has classified four grades of ferritic cast steels according to the temperature at which they retain an impact strength of 15 ft-lb. as measured with the Charpy keyhole-notch test specimen. This classification is shown for a plain carbon steel, a carbon-molybdenum steel, and two grades of nickel steel, all of which are normally considered for low-temperature service.

Regardless of which grade the melt shop may be called upon to make, four major considerations are always given to the melting practice employed: residual gases, metal cleanliness, deoxidation practice, and metal composition.

Any form of impurities accumulated along the grain boundary reduce the impact strength. Oxides present in steel can be exogenous or indigenous, depending on their source. All products of deoxidation are classified as indigenous inclusions, while oxides that are not an inherent product of the steelmaking process, such as entrapped refractory particles, are classified as exogenous inclusions.

To minimize these inclusions for the production of clean steels, the following practices should be considered: (*a*) clean furnace bottoms, (*b*) low FeO content in the final slag, (*c*) a high residual manganese, (*d*) proper deoxidation, (*e*) a good refractory program, and (*f*) a well-adapted pouring practice.

Steels deoxidized with large additions of aluminum gave a higher inclusion count for a manganese-

High-Impact Steel . . .

silicon ratio of 3:1 than when the addition of aluminum is small. A combination of deoxidizers, for instance, manganese and aluminum together, is more effective as a deoxidizer than when used individually. This illustrates how steels can be deoxidized to low levels of oxygen and still remain relatively clean.

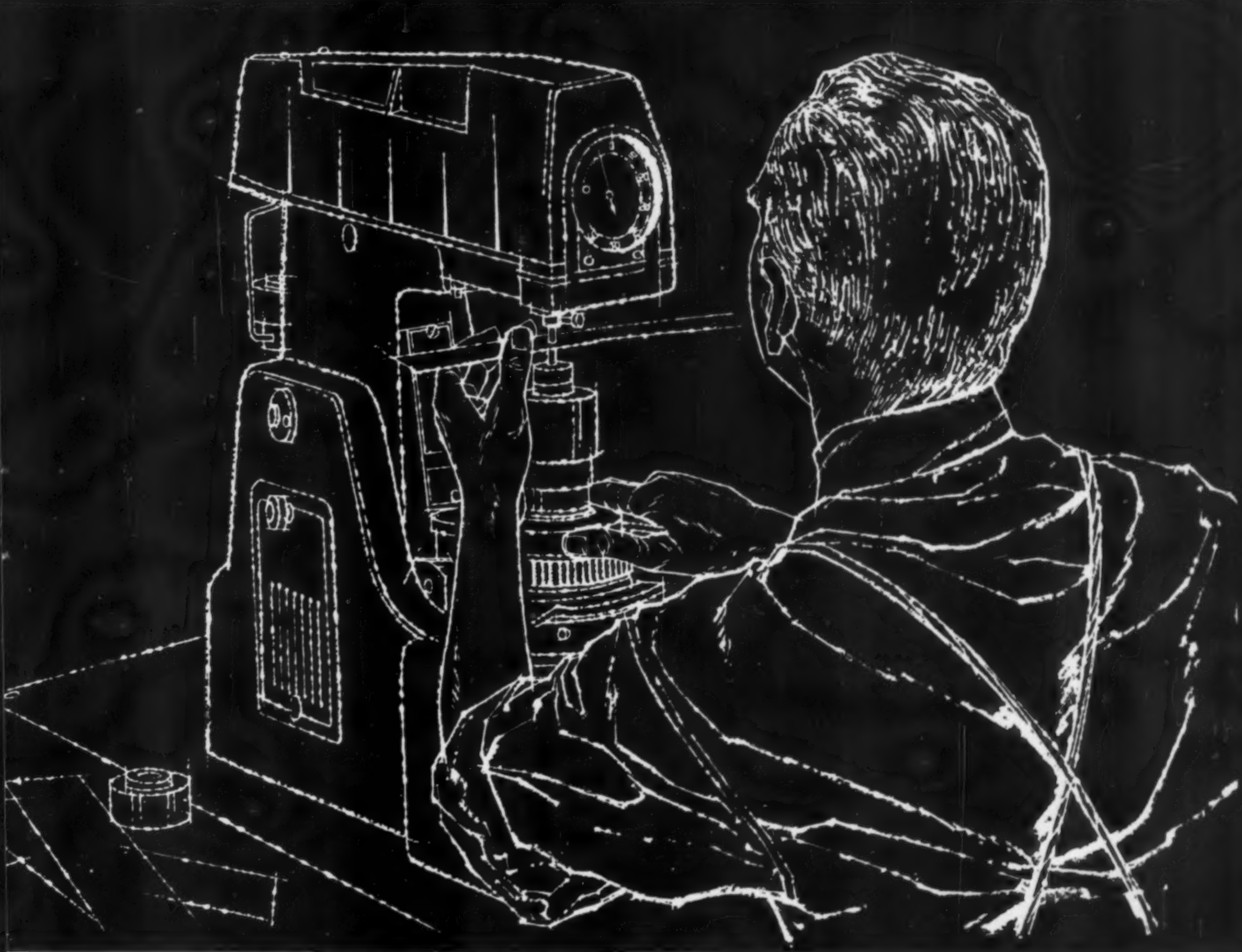
After the chemistry is adjusted and the heat is at the desired tapping temperature, furnace deoxidation proceeds by addition of the following deoxidizers in the sequence listed:

1. Siminal (20% Si, 20% Mn, 20% Al). As an initial deoxidizer, 3 lb. of Siminal per ton of metal charged is added.
2. Ferromanganese as required.
3. Ferrosilicon as required.

The taphole is plugged with a burlap bag to hold back the slag so that it will not interfere with ladle deoxidation. When the ladle is approximately two thirds full, high-purity aluminum eyebars are plunged into the molten metal, 2 lb. of aluminum being added per ton of steel tapped. When heats are to be shanked, an additional 1 lb. of aluminum per ton of metal is added to the metal stream in the form of high-purity aluminum shot as the shank ladle is filled.

Results of two heats of steel deoxidized by the factors described show impact tests of 28 to 34 ft-lb. at —50° F. for the plain carbon steel and 31 to 35 ft-lb. at —75° F. for carbon-molybdenum steel. The two nickel steels show good impact properties down to —100 and —150° F.

E. C. Wright



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Machining Beryllium

Digest of "Beryllium Machining Characteristics", by Donald Walker, *Mechanical Engineering*, Vol. 80, August 1958, p. 57-62.

ALTHOUGH beryllium is readily machined, certain precautions are necessary to avoid contaminating the atmosphere with toxic beryllium dust. One precaution is to use less cutting fluids.

Recent experiments have shown that, in machining beryllium, chips are usually formed by a brittle-fracture process. Cutting speed, feed rate and tool geometry seem to have little effect upon the fracture, although surface finish and chip uniformity improve with light feeds and high tool-rake angles. During the machining of beryllium, one meets such phenomena as surface cracking, stick-slip friction, and built-up-edge formation on the cutting tool.

To determine the effect of machining variables upon the beryllium oxide content of machining chips, tests were performed at various cutting speeds and effective rake angles. Data from these show that the oxide content of cutting chips is not strongly dependent upon either tool geometry or cutting speed.

Contrary to available information, the depth of cut did not seem to influence the number and severity of surface cracks remaining on the machined piece, although numerous cracks were found on all of the test specimens.

The tool-chip interface temperature increases rapidly with increasing cutting speed and less rapidly with increasing feed rate. At normal cutting speeds, tool-chip friction seems to be remarkably low, although this conclusion requires further study.

The effect of cutting speed and feed for finish-type cuts (feeds less than 0.010 in.) on the life of Carboloy 44 A tungsten-carbide tools was determined by measuring the rate of land growth. (This is generated on the clearance or flank face of the tool.) A relation was established between the tool life and cutting speed. Tool life is about the same as it is in machining steel, and greater than it is for machining titanium alloys. Ceramic tool life was not evaluated but should be extremely good.

A. J. SHALER

Physical tests at Standard include those for special properties of steel alloys under extreme variations in temperature. Here, the strength and ductility of steel are being checked for resistance to stress under severe conditions of elevated temperatures over a prolonged period of time.

Charpy impact and transition temperature determinations have recently assumed importance in many applications. Here a steel sample is immersed in liquid nitrogen to determine its susceptibility to fracture at temperatures as low as −300°F.

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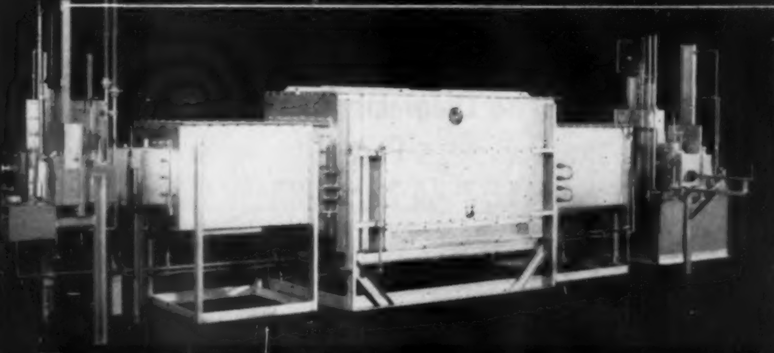
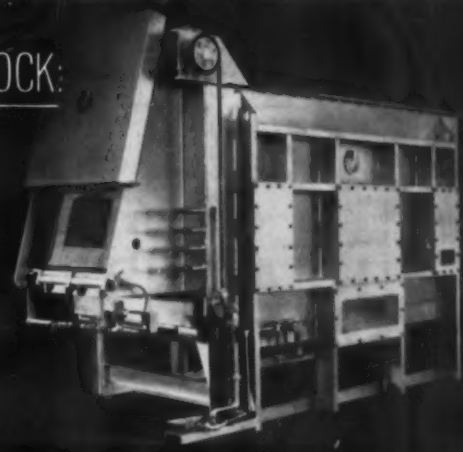
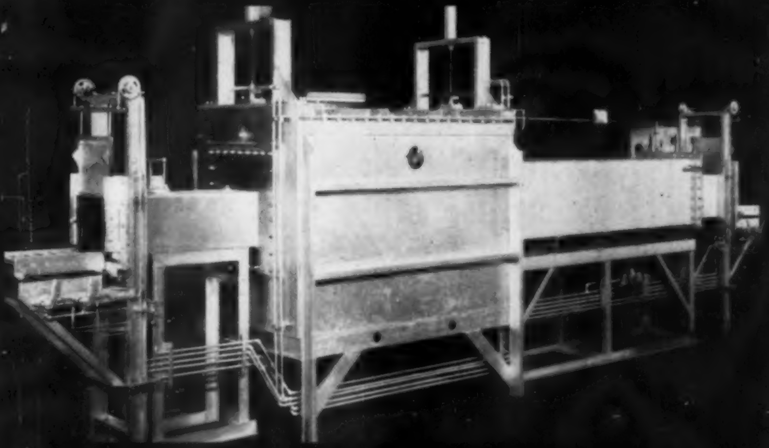


Sintering as many as 1250 UO_2 fuel pellets per hour in a hydrogen atmosphere, this Harper continuous pusher furnace is equipped for semi-automatic operation at temperatures up to 1750°C. Designed for gradual heating and cooling. Furnace has rugged moly heating elements, pressure relief vents, entrance and exit purge chambers.



Operating at temperatures as high as 1600°C, this single-ended batch furnace heats moly billets (up to 110 lbs./hr.) in a hydrogen atmosphere. Equipped with moly elements, it has two zones of heat control.



Sintering tungsten alloys (up to 75 lbs./hr.) in an atmosphere of dissociated ammonia, this moly furnace operates at temperatures as high as 1500°C. Designed for quick transfer from hot zone to cooling zone in atmosphere, it is equipped with pneumatically lifted refractory baffle doors for temperature uniformity.

Sintering stainless steel and tungsten powder parts at temperatures up to 2000°C, this Harper moly box furnace operates with mixtures of inert and reducing atmosphere gases.

MOLY FURNACES SUCCESSFUL UP TO 2000°C

As furnace operating temperatures rise above 1300°C (2350°F approx.), problems multiply. For example:

- What is the best combination of atmosphere and heating elements to obtain results desired?
- What refractories will prove most practicable from the standpoint of process, economy and service?
- Are purge chambers desirable or necessary?
- How should purge chamber doors be built to insure atmosphere-tight operation?
- When should automatic gas purging and automatic door sequence control be provided for quality, safety and economy?
- How should refractory baffle doors, roofs and hearths be constructed?

It takes experience to come up with the most profitable answers to questions like these in any given situation . . . *and Harper has experience to spare.* The four molybdenum heated units pictured above are but a few of many furnaces that have been built by Harper for high temperature applications. Among others are graphite tube models which perform with creditable success at 2750°C (5000°F approx.).

No matter what type of furnace you have in mind — box, pusher, mesh belt, roller hearth, bell, elevator or pit — Harper can supply it to operate most advantageously both temperature-wise and dollar-wise.

For more information, talk to your Harper representative or write: Harper Electric Furnace Corporation, 40 River Street, Buffalo 2, N. Y.

HARPER ELECTRIC FURNACES

FOR BRAZING, SINTERING, WIRE ANNEALING, BRIGHT ANNEALING, FORGING AND RESEARCH

The 14th METALLOGRAPHIC EXHIBIT

Chicago, November 1 to 6, 1959

*All metallographers—
everywhere—
are cordially invited to
display their best work.*

RULES FOR ENTRANTS

Exhibitors do not need to be members of the American Society for Metals.

Work which has appeared in previous metallographic exhibits held by the American Society for Metals is unacceptable.

Photographic prints should be mounted on stiff cardboard, extending no more than 3 in. beyond edge of print in any direction; maximum dimensions 14 by 18 in. (35 by 45 cm.). Heavy, solid frames are unacceptable.

Entries should carry a label on the *face of the mount* giving:

Classification of entry.

Material, etchant, magnification.

Any special information as desired.

The name, company affiliation and postal address of the exhibitor should be placed on the *back of the mount* together with a request for return of the exhibit if so desired.

Entrants living outside the United States should send their micros by first-class letter mail endorsed "Photo for Exhibition—May Be Opened for Customs Inspection".

Exhibits must be delivered before Oct. 15, 1959, either by prepaid express, registered parcel post or first-class letter mail, addressed:

Metallographic Exhibit
American Society for Metals
53 W. Jackson Blvd.
Chicago 4, Ill., U.S.A.

CLASSIFICATION OF MICROS

Class 1. Cast irons and steels.

Class 2. Carbon and alloy steels (wrought).

Class 3. Stainless steels and heat resisting alloys.

Class 4. Aluminum, magnesium, beryllium, titanium and their alloys.

Class 5. Copper, nickel, zinc, lead and their alloys.

Class 6. Uranium, plutonium, thorium, zirconium and reactor fuel and control elements.

Class 7. Metals and alloys not otherwise classified.

Class 8. Series showing transitions or changes during processing.

Class 9. Welds and other joining methods.

Class 10. Surface coatings and surface phenomena.

Class 11. Slags, inclusions, refractories, cermets and aggregates.

Class 12. Electron micrographs.

Class 13. Results by unconventional techniques.

Class 14. Color prints in any of the above classes. (No transparencies accepted.)

AWARDS AND OTHER INFORMATION

A committee of judges will be appointed by the Metal Congress management which will award a First Prize (a medal and blue ribbon) to the best in each classification. Honorable Mentions will also be awarded (with appropriate medals) to other photographs which in the opinion of the judges closely approach the winner in excellence. A Grand Prize, in the form of an engrossed certificate and a money award of $500 from the Adolph I. Buehler Endowment will also be awarded the exhibitor whose work is judged best in the show, and his exhibit shall become the property of the American Society for Metals for preservation and display in the Society's national headquarters.

All prize-winning photographs will be retained by the Society for one year and placed in a traveling exhibit to the various Chapters.

41st NATIONAL METAL CONGRESS & EXPOSITION

INTERNATIONAL AUDITORIUM — — — CHICAGO — — — NOV. 1 to 6, 1959

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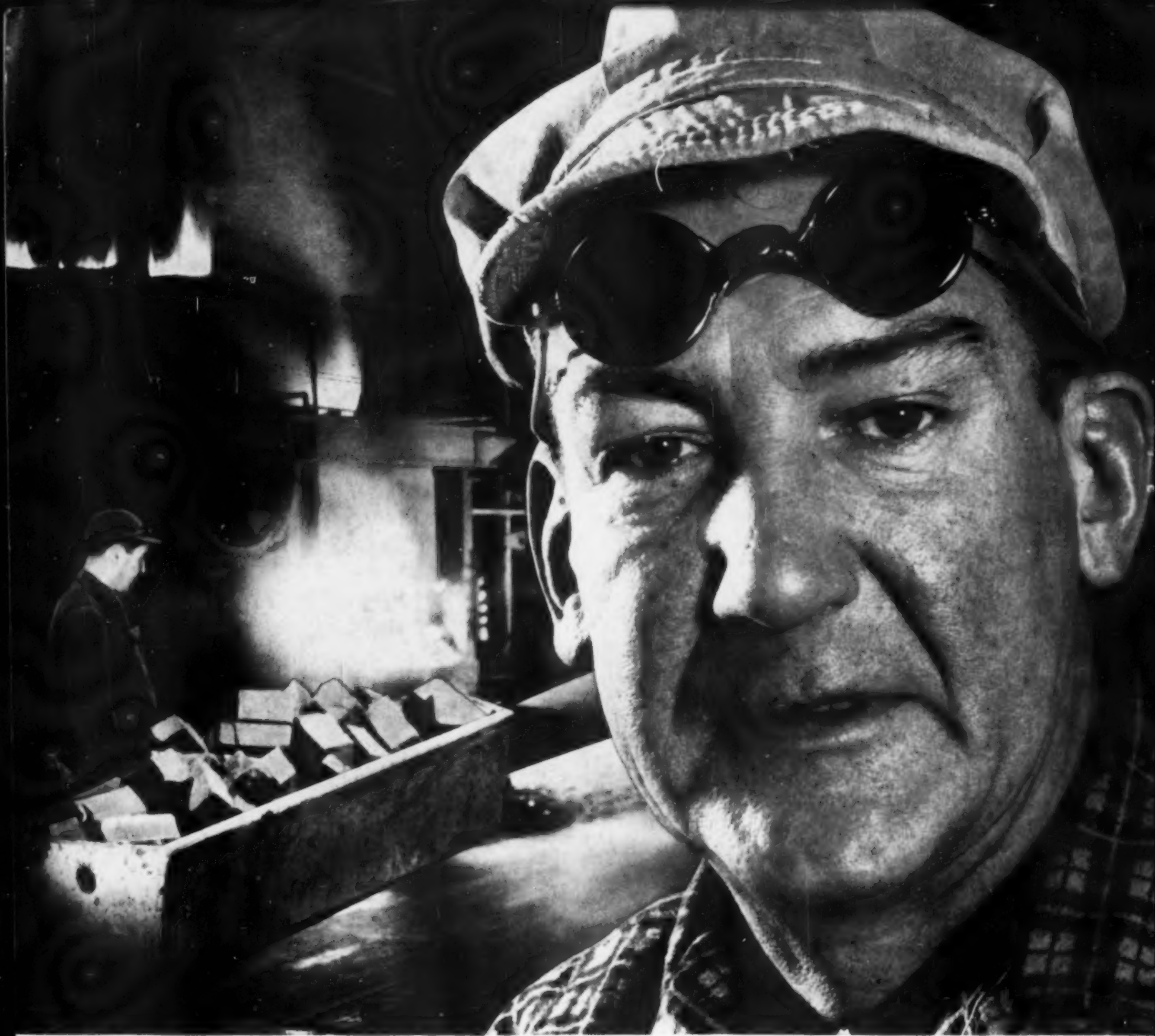


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